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CONTENTS

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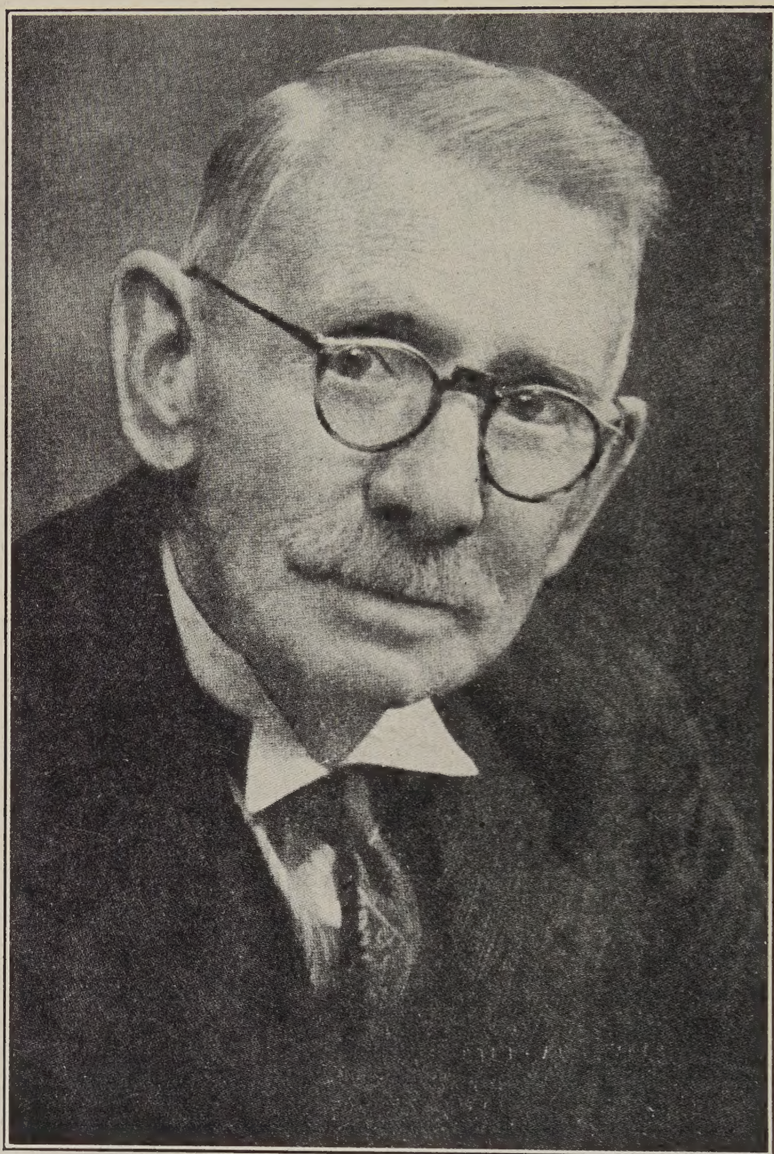

Terrestrial Magnetism
and
Atmospheric Electricity

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ON THE DETERMINATION OF MAGNETIC VERTICAL INTENSITY, Z, BY MEANS OF SURFACE INTEGRALS

BY JAMES H. TAYLOR

Introduction—The main result of the present paper is a separation of Z, the normal component of a magnetic field, into parts Z_e and Z_i due to external and internal sources, respectively. The resolution is given in terms of surface integrals whose integrands involve the observed surface values X and Z of the field. The paper may well be regarded as a sequel to an article by Vestine [1 of "References" at end of paper].

The author is greatly indebted to Dr. Vestine, who proposed the investigation and gave invaluable suggestions regarding it. The author is also grateful to Dr. Davids, who provided certain computational details relating to the eccentric dipole field, and who made available results that he had obtained which seemed to have a bearing on the problems under consideration.

Determination of Z from Poisson's integral—In a recent article Carathéodory [2] has pointed out the utility of the Poisson integral representation of a harmonic function. In case the function is harmonic in a region bounded by the surface of a sphere, such a representation seems particularly suitable.

Let $f(\theta, \phi)$ be a continuous function on the surface of a sphere of radius a. Let P having spherical coordinates (ρ, θ, ϕ), $\rho < a$, be any interior point. Then the function $V(P)$ given by Poisson's integral

$$V(P) = \frac{a^2-\rho^2}{4\pi a}\int_S \frac{f(Q)}{r^3}\,\mathrm{d}S \tag{1}$$

where Q is a surface point in the element of integration and r denotes the distance $\overline{PQ}$, is harmonic in the interior of the sphere. Moreover, as P approaches a surface point p, $V(P)$ approaches $f(p)$. That is, (1) is an explicit solution of the Dirichlet problem for the interior of the sphere. [Cf. Kellogg 3, pp. 240-243]. In particular if $f(\theta, \phi) \equiv 1$ the resulting harmonic function is $V(P) \equiv 1$. Thus we have the identity

$$1 = \frac{a^2-\rho^2}{4\pi a}\int_S \frac{\mathrm{d}S}{r^3}, \quad \rho \leqq a \tag{2}$$

Let p be an arbitrary but definitely selected point on the surface. It is desired to compute the directional derivative of $V(P)$ for $P=p$ in the direction of the inward pointing normal to the surface. Let p, P have coordinates (a, θ, ϕ), (ρ, θ, ϕ) respectively. By means of (1) and (2), and the fact that $V(p) = \lim_{P\to p} V(P) = f(p)$ we have

$$\left.\frac{\partial V(P)}{\partial \eta_i}\right]_{P=p} = \lim_{(a-\rho)\to+0} \frac{V(P)-V(p)}{a-\rho}$$

$$= \lim_{(a-\rho)\to+0} \frac{\dfrac{a^2-\rho^2}{4\pi a}\displaystyle\int_S \frac{f(Q)-f(p)}{r^3}\,\mathrm{d}S}{a-\rho} \tag{3}$$

provided the limit exists. Since the limit of a product is equal to the product of the limits of the factors,

$$\left.\frac{\partial V(P)}{\partial \eta_i}\right]_{P=p} = \frac{1}{2\pi} \lim_{(a-\rho)\to+0} \int_S \frac{f(Q)-f(p)}{r^3}\,\mathrm{d}S \tag{4}$$

For convenience we set $t=a-\rho$, the distance $\overline{Pp}$; then $\rho\to a$ from below is equivalent to $t\to 0$ from above, that is, through positive values. Also, let $I\ (t, \theta, \phi)$ denote the integral in (4). The parameter t in $I\ (t, \theta, \phi)$ enters only through r. Let ψ stand for one-half the angle between the radii through p and Q. Then an application of the Law of Cosines to the triangle PpQ yields the result

$$r^2 = t^2 + 4a(a-t)\sin^2\psi > 0 \text{ for } 0 < t \leqq a$$

Hence the integrand of the integral in (4) is continuous in its arguments for $0 < t \leqq a$, and therefore $I(t, \theta, \phi)$ is continuous in t in the open interval $0 < t \leqq a$.

We now consider the existence of $I(0, \theta, \phi)$, that is, the convergence of the (improper) integral

$$\int_S \frac{f(Q)-f(p)\,\mathrm{d}S}{r^3} \tag{5}$$

Here r is the distance, or length of chord, $\overline{pQ}$ and hence approaches zero as the variable point Q approaches p.

Let σ be a small spherical cap with p as center. We write

$$\int_S = \int_{S-\sigma} + \int_\sigma \quad \text{or} \quad \int_S - \int_{S-\sigma} = \int_\sigma$$

and consider

$$\lim_{\sigma\to 0}\left|\int_S - \int_{S-\sigma}\right| = \lim_{\sigma\to 0}\left|\int_\sigma\right|$$

Let (ρ, ϕ) be polar coordinates with origin at p in the tangent plane to the sphere at the point p. Then with σ sufficiently small the integral

$$\int_\sigma \frac{f(Q)-f(p)}{r^3}\,\mathrm{d}S \tag{6}$$

is arbitrarily closely approximated by

$$k\int_{\sigma'} \frac{f(Q')-f(p)}{\rho^3}\,\mathrm{d}S', \quad k=\text{constant} \tag{6$'$}$$

where the quantities in (6′) are the orthogonal projections on the tangent plane of the corresponding ones of (6).

We now make the additional assumption that $f(\theta, \phi)$ has continuous partial derivatives of the second order. Then the integrand of (6′) may be written in the form

$$\frac{1}{\rho^2}\frac{\partial f(0,\phi)}{\partial \rho}+\frac{1}{2\rho}\frac{\partial^2 f(\rho_0,\phi)}{\partial \rho^2}$$

where $0<\rho_0<\rho\leqq\rho'$, ρ' being the radius of σ'. The directional derivative of f in a direction $\mathbf{h}$, where $\mathbf{h}$ is a unit (tangential) vector, is given by $\mathbf{h}\cdot\mathbf{grad\ f}$. Let $\phi=\phi_0$ specify the direction of the gradient of f at p. Then

$$\frac{\partial f(0,\phi)}{\partial \rho}=\left|\mathbf{grad\ f}\right|_{\text{at}\,p}\cos(\phi-\phi_0)$$

Thus the convergence of (6′) depends on the convergence of the integrals

$$\int_{\sigma'}\frac{\cos(\phi-\phi_0)\,\mathrm{d}S'}{\rho^2}\quad\text{and}\quad\int_{\sigma'}\frac{\partial^2 f(\rho_0,\phi)}{\partial\rho^2}\,\frac{\mathrm{d}S'}{\rho}$$

Since $\partial^2 f(\rho_0,\phi)/\partial\rho^2$ is supposed bounded in the closed region the second integral converges to zero as $\sigma'\to 0$. The first integral, or

$$\int_{\sigma'}\frac{\cos\phi\,\mathrm{d}S'}{\rho^2}$$

where for convenience ϕ_0 has been taken equal to zero, is likewise convergent at least for some modes of approach. For instance, each of the iterated integrals

$$\lim_{\rho_1\to 0}\left[\lim_{\epsilon\to 0}\left\{\int_0^{2\pi}\left(\int_{\epsilon>0}^{\rho_1>\epsilon}\frac{\rho\mathrm{d}\rho}{\rho^2}\right)\cos\phi\mathrm{d}\phi\right\}\right]$$

$$\lim_{\rho_1\to 0}\left[\lim_{\epsilon\to 0}\left\{\int_{\epsilon>0}^{\rho_1>\epsilon}\left(\int_0^{2\pi}\cos\phi\mathrm{d}\phi\right)\frac{\rho\mathrm{d}\rho}{\rho^2}\right\}\right]$$

converges to zero. Because of symmetry relations, if $\triangle_1 S$ is an element of area about (ρ_1,ϕ_1) and $\triangle_2 S$ is a corresponding element about $(\rho_1,\pi-\phi_1)$ it follows that the sum of the two terms in the definition of the definite integral is zero. It is evident that the integral (6′) is not *absolutely* convergent.

Hence we conclude that $I(0,\theta,\phi)$ exists where the symbol is defined by

$$I(0,\theta,\phi)\equiv I_S(0,\theta,\phi)=\lim_{\sigma\to 0}\lim_{t\to 0}I_{S-\sigma}(t,\theta,\phi)$$

However, $\lim_{t\to 0}I_S(t,\theta,\phi)$, that is, $\lim_{t\to 0}\lim_{\sigma\to 0}I_{S-\sigma}(t,\theta,\phi)$ is needed also. We write

$$|I_S(t,\theta,\phi)-I_S(0,\theta,\phi)|=|I_{S-\sigma}(t,\theta,\phi)+I_\sigma(t,\theta,\phi)-I_{S-\sigma}(0,\theta,\phi)-I_\sigma(0,\theta,\phi)|$$
$$\leqq|I_{S-\sigma}(t,\theta,\phi)-I_{S-\sigma}(0,\theta,\phi)|+|I_\sigma(t,\theta,\phi)-I_\sigma(0,\theta,\phi)|$$

Because of the continuity of the integrand, for any $\sigma\neq 0$, and for all positive $t\leqq t_1$, with t_1 sufficiently small, the first absolute value term on the right will be less than ϵ where ϵ is a positive number arbitrarily chosen in advance. Select the "cap" σ sufficiently small so that the integral (6′) taken over its projection σ' in the tangent plane is numerically

less than ϵ. Then $|I_\sigma(0, \theta, \phi)| < \epsilon$, and $|I_\sigma(t, \theta, \phi)| < \epsilon$ for all t. In this latter case the convergence in σ is *uniform* with respect to t. Thus the second absolute term on the right in the above inequality can be made arbitrarily small, uniformly in t, by a proper choice of σ. Hence, $I_S(t, \theta, \phi)$ is a continuous function of t on the *closed* interval $0 \leqq t \leqq a$, and therefore

$$\lim_{t\to 0} I_S(t, \theta, \phi) = I_S(0, \theta, \phi) \tag{7}$$

It is convenient at this stage to think of the normal derivative vector as expressed in terms of the *outward pointing* normal of the surface. We designate it by the symbol Z_e and obtain at once from (4), (5) and (7)

$$Z_e(f, p) = -\frac{1}{2\pi}\int_S \frac{f(Q)-f(p)}{\bar{r}^3}\,\mathrm{d}S \tag{8}$$

At times we shall use the very explicit notation $Z_e(f, p)$. The letter Z will always mean the normal component of the gradient of a scalar potential V. Assuming V to be harmonic at all interior points of the sphere we shall suppose it is due to *external* sources; this is the meaning of the subscript e. The symbol f in $Z_e(f, p)$ indicates the surface values $f(\theta, \phi)$ of the potential V. Finally, p shows the surface point at which $Z_e(f, p)$ is evaluated.

Determination of $Z_i(f, p)$—Given the same surface function $f(\theta, \phi)$ as above, the Poisson integral

$$V_i(P) = \frac{\rho^2-a^2}{4\pi a}\int_S \frac{f(Q)}{r^3}\,\mathrm{d}S \tag{9}$$

defines a function $V_i(P)$ which is harmonic in the region exterior to the sphere, this implying regularity at infinity, and which takes on the assigned surface values. The identity corresponding to (2) is

$$\frac{\rho^2-a^2}{4\pi a}\int_S \frac{\mathrm{d}S}{r^3} = \frac{a}{\rho}, \quad \rho \geqq a \tag{10}$$

From the definition of a directional derivative

$$Z_i(p) = \lim_{(\rho-a)\to 0+} \frac{\rho+a}{4\pi a}\int_S \frac{f(\theta', \phi') - \frac{\rho}{a} f(\theta, \phi)}{r^3}\,\mathrm{d}S' \tag{11}$$

If one adds and subtracts the constant $f(\theta, \phi)$ in the numerator of the integrand of (11) the expression becomes

$$\frac{1}{2\pi}\lim_{\rho\to a+}\int_S \frac{f(\theta', \phi')-f(\theta, \phi)}{r^3}\,\mathrm{d}S' - \frac{f(\theta, \phi)}{a}\lim_{\rho\to a+}\frac{\rho^2-a^2}{4\pi a}\int_S \frac{\mathrm{d}S'}{r^3}$$

The first limit is the one considered above (4), and the second limit has the value unity according to (10). Hence Z in the direction of the *outward* pointing normal is given by

$$Z_i(f, p) = \frac{1}{2\pi}\int_S \frac{f(Q)-f(p)}{\bar{r}^3}\,\mathrm{d}S - \frac{f(p)}{a} \tag{12}$$

It follows at once by addition of (8) and (12) that

$$Z_e(f,p)+Z_i(f,p)=-\frac{f(p)}{a} \tag{13}$$

Transformation of the integral for Z_e—Let p be taken as the (north) pole of the coordinate system. Upon introducing the angle ψ equal to one-half the colatitude angle of Q the relation (8) becomes

$$Z_e(p)=-\frac{1}{2\pi}\int_S \frac{f(Q)-f(p)}{8a^3 \sin^3 \psi}\,\mathrm{d}S$$

We suppose this integral to exist, and hence it will be equal to each of its iterated integrals. Since $\mathrm{d}S=4a^2 \sin \psi \cos \psi \mathrm{d}\psi \mathrm{d}\phi$

$$\left.\begin{aligned} Z_e(p) &= -\frac{1}{2\pi}\int_0^{2\pi}\int_0^{\pi/2}\frac{f(Q)-f(p)}{2a}\csc^2\psi' \cos \psi' \mathrm{d}\psi' \mathrm{d}\phi' \\ &= -\frac{1}{2a}\int_0^{\pi/2}\int_0^{2\pi}\frac{f(Q)-f(p)}{2\pi}\csc^2\psi' \cos \psi' \mathrm{d}\phi' \mathrm{d}\psi' \end{aligned}\right\} \tag{14}$$

This relation has been obtained by Vestine [1, p. 36]. In his notation equation (14) reads

$$Z_e=-\frac{1}{2a}\int_0^{\pi/2}(\overline{V}_e-\overline{U}_e)\csc^2\psi \cos \psi \mathrm{d}\psi \tag{15}$$

However, according to our determination here, the other equations which correspond to those of Vestine (35) [1, p. 36] are

$$Z_i=\frac{1}{2a}\int_0^{\pi/2}(\overline{V}_i-\overline{U}_i)\csc^2\psi \cos \psi \mathrm{d}\psi-\frac{\overline{U}_i}{a} \tag{16}$$

and

$$Z=\frac{1}{2a}\int_0^{\pi/2}\{(\overline{V}_i-\overline{V}_e)-(\overline{U}_i-\overline{U}_e)\}\csc^2\psi \cos \psi \mathrm{d}\psi-\frac{\overline{U}_i}{a} \tag{17}$$

In the special case for which the *surface* values of V_i and V_e are the same (17) reduces to the relation (13).

Returning to the first integral in the right member of (14) we have

$$\int_0^{\pi/2}[f(Q)-f(p)]\csc^2\psi \cos \psi \mathrm{d}\psi=\int^{\pi/2}[f(Q)-f(p)]\csc \psi \cot \psi \mathrm{d}\psi$$

where each integral is of course defined by a limit with respect to its lower limit of integration. Let J stand for

$$J=\lim_{\epsilon\to 0+}\int_\epsilon^{\pi/2}[f(Q)-f(p)]\csc \psi \cot \psi \mathrm{d}\psi \tag{18}$$

We take $[f(Q)-f(p)]$ as u and $\csc \psi \cot \psi \mathrm{d}\psi$ as $\mathrm{d}v$ in the usual formula for integration by parts. Then

$$\begin{aligned} J &= \lim_{\epsilon\to 0+}\left\{-[f(Q)-f(p)]\csc \psi \Big|_\epsilon^{\pi/2}+\int_\epsilon^{\pi/2}\frac{\partial f(Q)}{\partial \psi}\csc \psi \mathrm{d}\psi\right\} \\ &= -[f(q)-f(p)]+\lim_{\epsilon\to 0+}\Big[\{f(\epsilon,\phi)-f(0,\phi)\}\csc \epsilon\Big]+2a\int_0^{\pi/2}X \csc \psi \mathrm{d}\psi \end{aligned} \tag{19}$$

where q denotes the south pole and X has its usual meaning (except possibly for algebraic sign),

$$X=\frac{1}{a}\frac{\partial f}{\partial \theta}=\frac{1}{2a}\frac{\partial f}{\partial \psi}$$

Since along a meridian, $\phi=$constant

$$f(\psi,\phi)-f(\psi_0,\phi)=2a\int_{\psi_0}^{\psi}X\mathrm{d}\psi$$

the quantity $[f(q)-f(p)]$ may be written in the form

$$f(q)-f(p)=2a\int_0^{\pi/2}X\mathrm{d}\psi \tag{20}$$

Now consider the indicated limit in (19). We write

$$\begin{aligned}\lim_{\epsilon\to 0}[f(\epsilon,\phi)-f(0,\phi)]\csc\epsilon &= a\lim_{\epsilon\to 0}\frac{f(\epsilon,\phi)-f(0,\phi)}{a\epsilon}\cdot\frac{\epsilon}{\sin\epsilon}\\ &= a \text{ times (directional derivative of } f \text{ at } p \text{ in direction } \phi)\\ &= aX(0,\phi).\end{aligned}$$

Hence

$$J=2a\int_0^{\pi/2}X(\csc\psi-1)\mathrm{d}\psi+aX(0,\phi)$$

and therefore $Z_e(p)$ is given by

$$\begin{aligned}Z_e(p)&=-\frac{1}{4\pi a}\int_0^{2\pi}J\mathrm{d}\phi\\ &=-\int^{\pi/2}\left\{\frac{1}{2\pi}\int_0^{2\pi}X\mathrm{d}\phi\right\}(\csc\psi-1)\mathrm{d}\psi\end{aligned}$$

since, as we have seen, $\int_0^{\pi/2}X(0,\phi)\mathrm{d}\phi=0$. Thus we finally have

$$Z_e(p)=-\int^{\pi/2}\overline{X}(\csc\psi-1)d\psi \tag{21}$$

where $\overline{X}=\frac{1}{2\pi}\int_0^{2\pi}X\mathrm{d}\phi$. It now follows from (13) that

$$Z_i(f,p)=\int_0^{\pi/2}\overline{X}(\csc\psi-1)\mathrm{d}\psi-\frac{f(p)}{a} \tag{22}$$

Verification of (13)—The important equation (13) can of course be established, independently of the preceding discussion, by the use of certain standard theorems concerning the discontinuities of a potential function and its normal derivative at points of a boundary. However, in this connection, it seems more interesting to investigate the relation (13) through the employment of spherical harmonics.

Let $H_n(x, y, z)$, $n \geqq 0$ be a homogeneous polynomial which satisfies Laplace's equation; that is, a *spherical harmonic* in the sense of Kellogg [3, p. 139]. Then $H_n(x, y, z)$ is harmonic in the interior of the sphere with center at the origin and radius a. It now follows by inversion with respect to the sphere (a Kelvin transformation), that the function

$$\frac{a}{\rho} H_n\left(\frac{a^2x}{\rho^2}, \frac{a^2y}{\rho^2}, \frac{a^2z}{\rho^2}\right)$$

is harmonic in the region exterior to the sphere and is regular at infinity. Moreover, the surface values of these two harmonic functions are the *same.* We transform to spherical coordinates and write

$$V_e = H_n(x, y, z) = \rho^n S_n(\theta, \phi)$$
$$V_i = \frac{a}{\rho} H_n\left(\frac{a^2x}{\rho^2}, \frac{a^2y}{\rho^2}, \frac{a^2z}{\rho^2}\right) = \frac{a^{2n+1}}{\rho^{n+1}} S_n(\theta, \phi)$$

Now

$$Z_e = na^{n-1} S_n(\theta, \phi)$$
$$Z_i = -(n+1)a^{n-1} S_n(\theta, \phi)$$

Therefore,

$$Z_e(p) + Z_i(p) = -a^{n-1} S_n(\theta, \phi) = -\frac{1}{a} V(p)$$

This verifies (13) for a single spherical harmonic.

The following *linearity relations* hold. Since differentiation and integration are linear operations, Z is obtained by a linear operator acting on V. If we write $Z_e = L(V_e)$ then $L(\alpha V_{1e} + \beta V_{2e}) = \alpha L(V_{1e}) + \beta L(V_{2e})$ for α, β arbitrary constants. That is, if $V_{3e} = \alpha V_{1e} + \beta V_{2e}$, α, β constants then $Z_{3e} = \alpha Z_{1e} + \beta Z_{2e}$ and similarly $Z_{3i} = \alpha Z_{1i} + \beta Z_{2i}$. Therefore $(Z_{3e} + Z_{3i}) = \alpha(Z_{1e} + Z_{1i}) + \beta(Z_{2e} + Z_{2i})$. This means that if (13) holds for surface values $f_1(\theta, \phi)$ and $f_2(\theta, \phi)$ separately it holds likewise for $f_3(\theta, \phi) = \alpha f_1(\theta, \phi) + \beta f_2(\theta, \phi)$ α, β constants.

Having verified that (13) is true for any spherical harmonic we now see that it must be true for any finite linear combination, with constant coefficients, of spherical harmonics, and also in the limit for any convergent sum. Inasmuch as any function harmonic throughout the interior of a sphere can be expressed as a suitable series of spherical harmonics with constant coefficients, we conclude that (13) must be a true relation for any two potential functions V_e and V_i, harmonic inside and outside the sphere, respectively, and which take on the *same* surface values.

Comparison of certain results with those of N. Davids—About the time this study was undertaken Dr. Davids obtained expressions for Z_e and Z_i (privately communicated) similar to (21) and (22). His results were obtained under slightly more restrictive hypotheses which we shall not attempt to state here; the method employed was that of spherical harmonic analysis. In the case of Z_e (21) checks the result of Davids as he had obtained precisely the same formula. However, the formula corresponding to (22) which he obtained is [see pp. 239-242 following]

$$Z_i^* = \int_0^{\pi/2} \overline{X}(\csc \psi + \cos 2\psi) d\psi \tag{23}$$

The particular example $V_i = a/\rho$, $\rho \geqq a$ which is harmonic outside the sphere including regularity at infinity, and which assumes the constant surface value unity shows that (22) and (23) are not strictly equivalent. That is one of the cases which Davids explicitly excluded.

A necessary and sufficient condition for the equivalence of (22) and (23) is

$$\int_0^{\pi/2} \overline{X}(\cos 2\psi + 1)d\psi = -\frac{f(p)}{a} \tag{24}$$

or

$$\frac{1}{2\pi}\int_0^{2\pi}\int_0^{\pi/2} X(Q)(\cos 2\psi+1)d\psi d\phi = -\frac{f(p)}{a}$$

Integrating by parts one obtains

$$\int_0^{\pi/2} X(Q)(\cos 2\psi+1)d\psi = \frac{1}{2a}\int_0^{\pi/2}\frac{\partial f(Q)}{\partial\psi}(\cos 2\psi+1)d\psi$$

$$= \frac{1}{2a}\Big[f(Q)(\cos 2\psi+1)\Big]_0^{\pi/2} + \frac{1}{a}\int_0^{\pi/2} f(Q)\sin 2\psi d\psi$$

$$= -\frac{f(p)}{a} + \frac{1}{a}\int_0^{\pi/2} f(Q)\sin 2\psi d\psi$$

Hence the imposed condition (24) is equivalent to

$$\int_0^{2\pi}\int_0^{\pi/2} f(Q)\sin 2\psi d\psi d\phi = 0$$

or

$$\int_S f(Q)dS = 0$$

or finally

$$\int_S f(Q)P_0(\mu)dS = 0 \tag{25}$$

since the Legendre polynomial of degree zero, $P_0(\mu) \equiv 1$. The relation (25) is known to hold for any surface spherical harmonic $S_n(Q)$, $n \neq 0$. Kellogg [3, p. 252]. Hence we conclude that (22) and (23) yield the same result if $f(Q)$, when expressed as a sum of surface harmonics, $f(Q) = S_0(Q) + S_1(Q) + S_2(Q) + \ldots$, has no constant term, that is, the constant term $S_0(Q)$ has the value zero.

The main problem—Let the given surface values be designated by a function $h(\theta, \phi)$ and let $f(\theta, \phi)$, $g(\theta, \phi)$ be an unknown resolution of $h(\theta, \phi)$ such that $h(\theta, \phi) = f(\theta, \phi) + g(\theta, \phi)$. We identify $f(\theta, \phi)$ as the surface values of a potential function $V_e(f, P)$, harmonic inside the sphere and which is the potential arising from all the *external* sources. Similarly $g(\theta, \phi)$ is associated with a potential function $V_i(g, P)$ due to all the *internal* sources. The potential functions are given by Poisson's integrals

$$V_e(f, P) = \frac{a^2-\rho^2}{4\pi a}\int_S \frac{f(Q)}{r^3}dS, \quad \rho < a$$

$$V_i(g, P) = \frac{\rho^2-a^2}{4\pi a}\int_S \frac{g(Q)}{r^3}dS, \quad \rho > a$$

where P has coordinates (ρ, θ, ϕ), Q is a surface point of the sphere in the element of integration, and r is the distance $\overline{PQ}$.

We define the symbol $V_e(f, p)$ to mean the limit of $V_e(f, P)$ as P approaches p. Since this limit is $f(p)$ we have $V_e(f, p)=f(p)$; similarly, $V_i(g, p)=g(p)$. It now follows from (8) and (12), with f replaced by g in the latter, that

$$Z_e(f, p)-Z_i(g, p)=-\frac{1}{2\pi}\int_S\frac{h(Q)-h(p)}{r^3}\,\mathrm{d}S+\frac{g(p)}{a} \tag{26}$$

If one takes p as the pole of the coordinate system and introduces the mean values $\bar{h}(Q)$ around parallels of latitude, and finally notes that $g(p)$ may be written in the form $[h(p)-f(p)+g(p)]/2$, it will be found that equation (26) reduces to formula (24) of Vestine [1].

From (8) the integral in (26) has the value

$$\begin{aligned}
-\frac{1}{2\pi}\int_S\frac{h(Q)-h(p)}{r^3}\,\mathrm{d}S&=Z_e(h, p)\\
&=Z_e(f, p)+Z_e(g, p) \qquad \text{[linearity]}\\
&=Z_e(f, p)-Z_i(g, p)-\frac{g(p)}{a} \qquad \text{by (13)}
\end{aligned}$$

This result corresponds to that obtained by Vestine [1, p. 35], where, however, there seems to be an error in algebraic sign.

We now have the equations

$$\left.\begin{aligned}
Z_e(f, p)-Z_i(g, p)&=Z_e(h, p)+\frac{g(p)}{a}\\
Z_e(f, p)+Z_i(g, p)&=Z(f, g, p)
\end{aligned}\right\} \tag{27}$$

where the second equation *defines* the symbol $Z(f, g, p)$. Since $Z_e(h, p)$ can be computed from the known surface values $h(Q)$ by means of formula (8), and $Z(f, g, p)$ may be regarded as the *observed* normal force component, the equations (27) serve to determine $Z_e(f, p)$ and $Z_i(g, p)$ in terms of a single function $g(p)$. However, $g(p)$ is an *unknown* function. We therefore seek an additional independent relation which involves it, hoping that the unknown function $g(p)$ may be thereby eliminated.

A convenient starting point is formula (21) of Vestine [1] which, in our notation, reads as follows

$$f(p)-g(p)=\frac{1}{2\pi}\int_0^{2\pi}\int_0^{\pi/2}[h(Q)+2aZ(f, g, Q)]\cos\psi\,\mathrm{d}\psi\,\mathrm{d}\phi \tag{28}$$

Combining this with $[f(p)+g(p)]=h(p)$ yields

$$g(p)=\frac{1}{2}\left\{h(p)-\frac{1}{2\pi}\int_0^{2\pi}\int_0^{\pi/2}[h(Q)+2aZ(f, g, Q)]\cos\psi\,\mathrm{d}\psi\,\mathrm{d}\phi\right\} \tag{29}$$

In geomagnetic applications the relation (29) serves to give $g(p)$ in terms of the observed quantity $Z(f, g, p)$ and $h(Q)$. The quantity $h(Q)$ may be presumed known since it can be computed from the measured tangential component $X(h, Q)$.

In passing we note that (29) is compatible with (13) for $f(Q)=g(Q)=h(Q)/2$. In this case the integrand of (29) vanishes identically as $[h(Q)+2aZ(f, g, Q)]$ may be written in the form $\{2g(Q)+2a[Z_e(g, Q)+Z_i(g, Q)]\}$ which vanishes by (13).

We now return to equations (27) and from them obtain

$$Z_e(f, p)=\frac{1}{2}\left\{Z_e(h, p)+Z(f, g, p)+\frac{g(p)}{a}\right\} \tag{30}$$

Formula (21) provides a method of computing $Z_e(h, p)$ from the observed surface values. The quantity $Z(f, g, p)$ can be observed directly; however, it may prove convenient to combine it with $g(p)/a$. We add $Z(f, g, p)$ to each member of (29). Now since $Z(f, g, p)$ and $h(p)$ are constants with respect to the integration, and since

$$\int_0^{2\pi}\int_0^{\pi/2}\cos\psi d\psi d\phi=2\pi$$

the equation (29) may be written in the form

$$Z(f, g, p)+\frac{g(p)}{a}=-\frac{1}{4\pi a}\int_0^{2\pi}\int_0^{\pi/2}\{[h(Q)-h(p)]+2a[Z(f, g, Q)-Z(f, g, p)]\}\cos\psi d\psi d\phi \tag{31}$$

An integration by parts applied to the first integral on the right yields

$$\int_0^{\pi/2}[h(Q)-h(p)]\cos\psi d\psi=2a\int_0^{\pi/2}X(h, Q)(1-\sin\psi)d\psi$$

With this substitution (31) becomes

$$Z(f,g,p)+\frac{g(p)}{a}=-\frac{1}{2\pi}\int_0^{2\pi}\int_0^{\pi/2}\{X(h, Q)(1-\sin\psi)+[Z(f,g,Q)-Z(f,g,p)]\cos\psi\}d\psi d\phi \tag{32}$$

Upon introducing the mean values around parallels of latitude in (32) and making use of (21) the formula (30) becomes

$$Z_e(f, p)=-\frac{1}{2}\int_0^{\pi/2}\{\overline{X}(h, \psi)(\csc\psi-\sin\psi)+[\overline{Z}(f, g, \psi)-Z(f, g, 0)]\cos\psi\}d\psi \tag{33}$$

or its equivalent

$$Z_e(f, p)=-\frac{1}{2}\int_0^{\pi/2}\{\overline{X}(h, \psi)\cot\psi+\overline{Z}(f, g, \psi)-Z(f, g, 0)\}\cos\psi d\psi \tag{34}$$

Applications of (34) to certain special cases—Suppose (34) yields the correct result for the two special cases: (A), $h(Q)=f(Q)$, $g(Q)=0$; and (B), $h(Q)=g(Q)$, $f(Q)=0$. We now consider the application of (34) to (C): $h(Q)=[\alpha f(Q)+\beta g(Q)]$, where α, β are two independent parameters which are also independent of the other variables. Linearity considerations imply the following relations.

$$Z_e(\alpha f, Q)=\alpha Z_e(f, Q), \qquad Z_i(\beta g, Q)=\beta Z_i(g, Q)$$

and hence

$$Z(\alpha f, \beta g, Q)=\alpha Z_e(f, Q)+\beta Z_i(g, Q) \tag{35}$$

In particular $Z(\alpha f, 0, Q)=\alpha Z_e(f, Q)$ and $Z(0, \beta g, Q)=\beta Z_i(g, Q)$. We also have

$$X(\alpha f+\beta g, Q)=\alpha X(f, Q)+\beta X(g, Q) \tag{36}$$

Finally we note that the average values $\overline{X}$ satisfy (36) and $\bar{Z}$ satisfy (35). In view of these relations an examination of the integrand of (34) reveals that if (34) yields a valid result when applied to the cases (A) and (B) separately, it must do likewise when applied to the more general case (C).

As a precautionary measure we note that $Z(f, g, Q)$ is obtained from the functions f and g by an operation which is *non-linear*. That is

$$Z(\alpha f_1+\beta f_2, g, Q)\neq \alpha Z(f_1, g, Q)+\beta Z(f_2, g, Q)$$

for

$$\begin{aligned} Z(\alpha f_1+\beta f_2, g, Q) &= Z_e(\alpha f_1+\beta f_2, Q)+Z_i(g, Q) \\ &= \alpha Z_e(f_1, Q)+\beta Z_e(f_2, Q)+Z_i(g, Q) \end{aligned}$$

whereas

$$\alpha Z(f_1, g, Q)+\beta Z(f_2, g, Q)=\alpha Z_e(f_1, Q)+\beta Z_e(f_2, Q)+(\alpha+\beta)Z_i(g, Q)$$

With $h(Q)=[\alpha f(Q)+\beta g(Q)]$ formula (34) becomes

$$\begin{aligned} \alpha Z_e(f, p) = &-\frac{1}{2}\int_0^{\pi/2} \alpha\{\overline{X}(f, \psi) \cot \psi+\overline{Z}_e(f, \psi)-Z_e(f, 0)\} \cos \psi d\psi \\ &-\frac{1}{2}\int_0^{\pi/2} \beta\{\overline{X}(g, \psi) \cot \psi+\overline{Z}_i (g, \psi)-Z_i(g, 0)\} \cos \psi d\psi \end{aligned}$$

Since this is an *identity* in α, β it must be that

$$Z_e(f, p)=-\frac{1}{2}\int_0^{\pi/2} \{\overline{X}(f, \psi) \cot \psi+\overline{Z}_e(f, \psi)- Z_e(f, 0)\} \cos \psi d\psi \tag{37}$$

and

$$0=-\frac{1}{2}\int_0^{\pi/2} \{\overline{X}(g, \psi) \cot \psi+\overline{Z}_i(g, \psi)-Z_i(g, 0)\} \cos \psi d\psi \tag{38}$$

Equation (37) may be written in the equivalent form

$$Z_e(f, p)=-\int_0^{\pi/2} \{\overline{X}(f, \psi)(\csc \psi-\sin \psi)+\overline{Z}_e(f, \psi) \cos \psi\}d\psi \tag{39}$$

This relation should, of course, be consistent with (21). A necessary and sufficient condition for this is

$$\int_0^{\pi/2} \{\overline{X}(f, \psi)(\sin \psi-1)-\overline{Z}_e(f, \psi) \cos \psi\}d\psi=0$$

or

$$\frac{1}{2\pi}\int_0^{2\pi}\int_0^{\pi/2} \{X(f, Q)(\sin \psi-1)-Z_e(f, Q) \cos \psi\}d\psi d\phi=0 \tag{40}$$

An integration by parts gives

$$\int_0^{\pi/2} X(f, Q)(\sin \psi-1)d\psi=\frac{f(p)}{2a}-\frac{1}{2a}\int_0^{\pi/2} f(Q) \cos \psi d\psi$$

By means of this (40) becomes

$$\frac{1}{2\pi}\int_0^{2\pi}\frac{f(p)}{2a}\,d\phi-\frac{1}{4\pi a}\int_0^{2\pi}\int_0^{\pi/2}[f(Q)+2aZ_e(f,Q)]\cos\psi d\psi d\phi=0$$

or

$$f(p)=\frac{1}{2\pi}\int_0^{2\pi}\int_0^{\pi/2}\{f(Q)+2aZ_e(f,Q)\}\cos\psi d\psi d\phi$$

This is just (28) for $g\equiv 0$. Similarly it can be shown that (38) is equivalent to (28) with $f(Q)\equiv 0$ and $h(Q)=g(Q)$. This return to (28) provides at least a partial check on the computations between (28) and (34).

If it is assumed that the Earth's magnetic field is the gradient of a scalar potential due to a distribution of actual physical sources, there is ample evidence to the effect that the field is due principally to internal sources. The harmonic analysis carried out by Dyson and Furner may indicate, in terms of the scalar potential, that about 97 per cent is due to internal sources. This important physical problem makes it of some interest to investigate the normal component Z for such a uniform "split" of the surface scalar potential values.

Let then $h(Q)$ be a given scalar field defined on the surface, and let α, β be two non-negative real *constants* whose sum is unity, that is, $(\alpha+\beta)=1$. Take $f(Q)=\alpha h(Q)$ and $g(Q)=\beta h(Q)$. Relation (35) applied to this particular case gives $Z(\alpha h, \beta h, p)=\alpha Z_e(h, p)+\beta Z_i(h, p)$.

It is proposed to compare the "observed" force component $Z(\alpha h, \beta h, p)$ for given α, β with the theoretical value which results from the supposition that the potential is due entirely to internal sources. This latter case is provided by $\alpha=0$, $\beta=1$. Let the ratio $[Z(\alpha h, \beta h, p)/Z_i(h, p)]$ be designated by $\lambda(\alpha, p)$. Then

$$\lambda(\alpha, p)=\alpha\frac{Z_e(h, p)}{Z_i(h, p)}+\beta \qquad \text{for } Z_i(h, p)\neq 0$$

Since $\beta=1-\alpha$, we have

$$\lambda(\alpha, p)=\alpha\left(\frac{Z_e(h, p)}{Z_i(h, p)}-1\right)+1$$

$$=-\frac{\alpha}{a}\frac{h(p)}{Z_i(h, p)}+1-2\alpha$$

by use of (13). Hence a necessary and sufficient condition that $\lambda(\alpha, p)$ be a *constant* as regards p is $h(p)=\sigma Z_i(h, p)$ where σ is a constant independent of p. This relation evidently holds in case $h(Q)$ consists of a single spherical harmonic of arbitrary degree, but it does not hold for the sum of two spherical harmonics which are linearly independent. Thus we see that a constant ratio (g/h) of the scalar fields does not necessarily imply that the ratio (Z_i/Z) will be constant.

In the derivation of (34) Z was taken in the direction of the outward pointing normal, that is, in the direction of increasing ρ, and X was taken in the direction of increasing θ. In any application to the Earth's magnetic field it is perhaps convenient to follow the usual conventions of measuring Z downward and X in the north direction. An examination

of (34) shows that these two changes in sign leave (34) unchanged. A similar remark applies to (21).

A trial evaluation of the integral (34) was made for the eccentric dipole approximating the Earth's magnetic field; the entries needed for the computation were taken from the charts appearing in the paper by J. Bartels [4]. The computed value for Z_e at the point on the equator with longitude 180° turned out to be 1.2 milligauss. This departure from the theoretically correct value zero indicates, in this example, the error arising from the method.

Remarks concerning the main problem—The real problem under consideration is: To devise a workable procedure which yields a reliable estimate of the value of $Z(f, g, p)$ at a point p on the Earth's surface where no observational value of Z is available, or where such observational value of Z is of doubtful validity. Here, "observational value of Z" is used in the sense that the value of Z is computed directly from the observed values of H, D, and I at the point.

We now face the fact that the result reached in (34) falls short of achieving the desired objective. The fundamental reason for this is that the very thing which is wanted, namely $Z(f, g, p)$, enters into the computation by which we seek to determine it. One may have the hope that $Z(f, g, p)$ enters in such manner that it will be largely overruled by $Z(f, g, Q)$ at other points Q of the surface where such values are believed to be reliable. However a superficial examination indicates that this may not be the case; indeed it may be that the rôle of $Z(f, g, p)$ in the integral of the right member of (34) is rather dominant. If we remove the constant $Z(f, g, p)$ from under the integral sign (34) takes the form

$$Z_e(f, p) = \frac{1}{2}Z(f, g, p) - \frac{1}{2}\int_0^{\pi/2} \{\overline{X}(h, \psi) \cot \psi + \overline{Z}(f, g, \psi)\} \cos \psi d\psi$$

Thus the error in $Z_e(f, p)$, when Z_e is computed in this manner, may be expected to be comparable to the error in $Z(f, g, p)$.

However, it appears that sufficient material is on hand to solve theoretically the main problem in a satisfactory manner. Since no separation of $h(Q)$ into $[f(Q)+g(Q)]$ can be made from a knowledge of $X(Q)$ only, it is clear that use must be made of additional information. The additional information which is available, and which is sufficient for our purpose, consists of the values of $Z(Q)$. Thus we cannot expect to *avoid entirely* the entry of $Z(f, g, p)$, the value of Z at the point p in question. Perhaps then the best that can be done is to cast $Z(f, g, p)$ in a framework in which it obviously plays no special rôle, but is merely on a par with any other value of Z used in the computation. By addition of the equations (27) one obtains

$$Z(f, g, p) = 2Z_e(f, p) - Z_e(h, p) - \frac{g(p)}{a} \tag{41}$$

For one particular point p an integration (29) provides $g(p)$; similarly the integration of (21) yields $Z_e(h, p)$. Also $Z_e(f, p)$ is given by (21). However, in order to apply this method to arrive at $Z_e(f, p)$ the value of f must be known not merely at the point p but at *every point* Q of a network on the surface considered sufficiently fine for our purpose. If

there are n such points Q_n, n evaluations of (29) would be preliminary to the use of (21) to determine $Z_e(f, p)$. Since this is probably an impracticable undertaking one looks for a suitable *simplifying assumption.* One which may be worth investigating is the assumption that the field f, due to external sources, is axially symmetric with respect to a line through the Earth's center. With this assumption one would abandon (29) for the computation of f and use instead (41) for the determination of $Z_e(f, p)$ at particular points $p_1, p_2, \ldots$, where the values of $Z(f, g, p)$ are considered reliable. Then with these estimated values of $Z_e(f, Q)$ around circles of latitude, with respect to the assumed axis of symmetry, one would use (41) to compute $Z(f, g, p)$ at a point p where its value is unknown or highly questionable.

Determination of $X_e(p)$ from surface values—Poisson's integral solves the Dirichlet problem; the analogous integral for the Neumann problem is

$$V_e(P)=\frac{1}{4\pi}\int_S Z_e(Q)\left(\frac{2}{r}+\frac{1}{a}\log\frac{2a}{a-\rho\cos\gamma+r}\right)dS+\text{constant} \tag{42}$$

with P: (ρ, θ, ϕ), Q: (a, θ', ϕ'), $r=\overline{PQ}=(a^2+\rho^2-2a\rho\cos\gamma)^{1/2}$, $\cos\gamma=\cos\theta\cos\theta'+\sin\theta\sin\theta'\cos(\phi-\phi')$. Now, at least for $\rho<a$

$$\frac{\partial V_e(P)}{\partial\theta}=\frac{1}{4\pi}\int_S Z_e(Q)\frac{\partial}{\partial\theta}\left(\frac{2}{r}+\frac{1}{a}\log\frac{2a}{a-\rho\cos\gamma+r}\right)dS$$

For convenience set $\mu=\cos\gamma$. Then

$$\frac{\partial V_e(\rho,\theta,\phi)}{\partial\theta}=\frac{1}{4\pi}\int_S Z_e(Q)\left(\frac{2a\rho}{r^3}+\frac{\rho r+a\rho}{ar(a-\rho\mu+r)}\right)\frac{\partial\mu}{\partial\theta}\,dS$$

We suppose the right member to be continuous for $\rho\leqq a$ and we select ϕ as $\phi=0$ and take p as the pole of the coordinate system. Then

$$\frac{\partial V_e(p)}{\partial\theta}=\frac{1}{4\pi}\int_S Z_e(Q)\left[\frac{2a^2}{\bar r^3}+\frac{a\bar r+a^2}{a\bar r(a-a\cos\theta'+\bar r)}\right]\sin\theta'\cos\phi'\,dS$$

Since $\bar r=2a\sin\psi$ with $2\psi=\theta'$, we have

$$X_e(p)=\frac{1}{2\pi}\int_0^{2\pi}\int_0^{\pi/2} Z_e(Q)(\cos 2\psi+\csc\psi)\cos\phi' d\psi d\phi' \tag{43}$$

It seems likely that a similar formula for $X_i(p)$ in terms of $Z_i(p)$ can be developed if one starts with the analogue of (42) which gives the potential function $V_i(P)$ exterior to the sphere. Unlike Z, for a given surface function $f(Q)$ there is no distinction, aside from mere notation, in $X_e(f, p)$ and $X_i(f, p)$. Thus by means of (13) we have from (43)

$$X_i(g, p)=-\frac{1}{2\pi}\int_0^{2\pi}\int_0^{\pi/2}\left\{Z_i(Q)+\frac{g(Q)}{a}\right\}(\cos 2\psi+\csc\psi)\cos\phi' d\psi d\phi' \tag{44}$$

We now consider the separation of X into parts due to internal and external sources. Equation (15) of Vestine [1] seems to afford a good starting point. We write the equation in the form

$$V_e(f, p) - V_i(g, p) = \frac{1}{2\pi} \int_S \left(\frac{Z(f, g, Q)}{r} - h(Q) \frac{\partial}{\partial \nu} \frac{1}{r} \right) dS$$

Differentiating this equation with respect to θ and evaluating for the point p one obtains

$$X_e(f, p) - X_i(g, p) = \frac{1}{4\pi a} \int_0^{2\pi} \int_0^{\pi/2} \{2aZ(f, g, Q) + h(Q)\} \cot \psi \cos \psi \cos \phi' \, d\psi d\phi' \qquad (45)$$

Since there is no difference in $X_e(f, p)$ and $X_i(f, p)$, and similarly for $X_e(g, p)$ and $X_i(g, p)$, an interchange of the functions f and g merely changes the sign of the left member. Employment of (13) verifies that the right member is likewise skew-symmetric in the arguments f and g.

For convenience let the right member of (45) be denoted by $H(f, g, p)$. We now have the equations

$$\left. \begin{aligned} X(f, p) - X(g, p) &= H(f, g, p) \\ X(f, p) + X(g,)p &= X(h, p) \end{aligned} \right\} \qquad (46)$$

where the indices e and i have been deleted from these symbols since they are without significance. The equations (46) provide the required resolution of X into parts $X(f, p)$ and $X(g, p)$. We see that $X(f, p)$ is given in terms of $X(h, p)$, the observed value of X at the point p in question, and a surface integral whose integrand involves $Z(f, g, Q)$, the observed normal component, and $h(Q)$ the surface potential.

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THE GEORGE WASHINGTON UNIVERSITY AND
DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTE OF WASHINGTON,
Washington, D. C., October 31, 1944

LETTERS TO EDITOR

(See also page 276)

PROVISIONAL SUNSPOT-NUMBERS FOR JUNE TO JULY, 1944

(Dependent alone on observation at Zürich Observatory)

Day	June	July
1	14	0
2	8	10
3	0	10
4	0	7
5	0	7
6	0	7
7	0	0
8	8	0
9	7*	0
10	8	8
11	7	8
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	8	0
18	8*	7
19	8	7
20	8	7
21	8	0
22	8[a]	8
23	8	8
24	8	13
25	8	7
26	7	7
27	7	0
28	7	*W* 14[c]
29	0	11
30	0	10
31		0
Means.......	4.8	5.0
No. days.....	30	31

Mean for quarter, April to June, 1944: 2.3 (91 days)

*Observed at Locarno.
[a]Passage of an average-sized group through the central meridian.
[b]Passage of a large group or spot through the central meridian.
[c]New formation of a group developing into a middle-sized or large center of activity: *E*, on the eastern part of the Sun's disk; *W*, on the western part; *M*, in the central-circle zone.
[d]Entrance of a large or average-sized center of activity on the east limb.

EIDGEN. STERNWARTE,
Zürich, Switzerland

W. BRUNNER

CALCULATION OF VERTICAL COMPONENT (Z) FOR POTENTIAL FIELDS FROM OBSERVED VALUES OF DECLINATION (D) AND HORIZONTAL INTENSITY (H)

By Norman Davids

If a vector field $F(r, \theta, \phi)$ is known to be derivable from a scalar potential, and if it is known how much of the field originates from sources inside the Earth, then the values of its three components D, H, Z, or X, Y, Z over the surface of a sphere $r=a$ are not independent; that is, there exists a functional operator which enables any one of the functions to be determined from the other two of the group. In practice, D and H are usually known with much greater accuracy than Z, so that an operator which enables Z to be calculated from D and H could be useful in determining Z in uncertain regions, or in testing the consistency of the Z-charts against the others. The method, however, requires the knowledge of D and H over the whole Earth—although local or regional inaccuracies are likely to neutralize each other in the final results.

Sources inside the Earth account for at least 95 per cent of the main field, so that the method can be applied to testing of the world-charts; it can be extended to some of the variation-fields as well.

(A) *Derivation of the formula*—The operator takes the form of an integral transformation, and is given by

$$Z(P)=\int_0^{\pi} G(\theta)\cdot \overline{X}\cdot d\theta \qquad (1)$$

where $G(\theta)=(\csc\ \theta/2+\cos\ \theta)/2$ and $\overline{X}=(1/2\pi)\int_0^{2\pi} H \cos D\, d\phi$. Here $H=H(\theta, \phi)$ and $D=D(\theta, \phi)$ are functions of position on the sphere and it should be noted that θ, ϕ are the colatitude and longitude referred to the given point P as pole.

Table 1 gives the values of the kernel, $G(\theta)$, at steps of $\theta=5°$.

Table 1—*Values of* $G(\theta)=(1/2)(\csc\ \theta/2+\cos\ \theta)$

θ	$G(\theta)$	θ	$G(\theta)$	θ	$G(\theta)$
°		°		°	
0	∞	60	1.25	120	0.75
5	11.96	65	1.14	125	0.80
10	6.22	70	1.04	130	0.86
15	4.32	75	0.95	135	0.95
20	3.35	80	0.86	140	1.08
25	2.76	85	0.78	145	1.26
30	2.36	90	0.70	150	1.50
35	2.08	95	0.69	155	1.86
40	1.84	100	0.69	160	2.41
45	1.66	105	0.69	165	3.35
50	1.50	110	0.70	170	5.25
55	1.37	115	0.72	175	10.96
				180	∞

According to the potential assumption, there exists a function $V(r, \theta, \phi)$ harmonic in space except for the sources, whose gradients (4) at the surface $r=a$ give the field-components there. When the sources are supposed to lie entirely inside the Earth there exist coefficients $I_{n,m}$ $i_{n,m}$ such that

$$V \doteq a \sum_{n=0}^{\infty} \sum_{m=0}^{n} (r/a)^{-(n+1)} I_{n,m} \sin (m\phi + i_{n,m}) P_{n,m}(\mu) \tag{2}$$

where $\mu = \cos \theta$ and

$$P_{n,m} (\mu) = \sin^m(\theta) \mathrm{d}^m P_n(\mu) / \mathrm{d}\mu^n \tag{3}$$

In particular, for $m=1$

$$P_{n,1}(\mu) = -\mathrm{d}P_n/\mathrm{d}\theta \tag{3a}$$

We then have, for $r=a$

$$\left.\begin{aligned}
X &= H \cos D = \partial V/a\partial\theta = \sum_{n=0}^{\infty} \sum_{m=0}^{n} I_{n,m} \sin(m\phi + i_{n,m}) \mathrm{d}P_{n,m}/\mathrm{d}\theta \\
Y &= H \sin D = -\partial V/a \sin \theta\partial\phi \\
&= (-1/\sin \theta) \sum_{n=0}^{\infty} \sum_{m=0}^{n} m I_{n,m} \cos (m\phi + i_{n,m}) \cdot P_{n,m}(\mu) \\
Z &= \partial V/\partial r = \sum_{n=0}^{\infty} \sum_{m=0}^{n} -(n+1) I_{n,m} \sin(m\phi + i_{n,m}) P_{n,m}(\mu)
\end{aligned}\right\} \tag{4}$$

The averages of these elements around parallels of latitude are, when $n>0$

$$\left.\begin{aligned}
\overline{X} &= -\sum_{n=1}^{\infty} I_{n,0} \sin i_{n,0} \cdot P_{n,1}(\mu) \\
\overline{Y} &= 0 \\
\overline{Z} &= -\sum_{n=1}^{\infty} (n+1)\, I_{n,0} \sin i_{n,0} \cdot P_n(\mu)
\end{aligned}\right\} \tag{5}$$

The problem now is to determine a function $F(\mu)$ such that (1) holds, that is

$$Z_{\mu=1} = -\sum_{n=1}^{\infty} (n+1) I_{n,0} \sin i_{n,0} = -\int_{-1}^{1} F(\mu) \sum_{1}^{\infty} I_{n,0} \sin i_{n,0} \cdot P_{n,1} (\mu) \mathrm{d}\mu \tag{6}$$

If this is to hold for arbitrary coefficients $I_{n,0}$, $i_{n,0}$, we must have

$$n+1 = \int_{-1}^{1} F(\mu) P_{n,1}(\mu) \mathrm{d}\mu \qquad (n=1, 2, \ldots) \tag{7}$$

If the undetermined function $F(\mu)$ is sufficiently regular, there exist coefficients a_s such that

$$F(\mu)=\sum_{s=1}^{\infty} a_s P_{s,1}(\mu)$$

(7) then becomes

$$n+1=\sum_{s=1}^{\infty} a_s \int_{-1}^{1} P_{s,1}(\mu)P_{n,1}(\mu)\mathrm{d}\mu=\frac{2n(n+1)}{2n+1}a_n$$

by virtue of the orthogonality property of the $P_{n,1}$ functions [see 1 of "References" at end of paper, §17.4]. This determines the coefficients a_n so that

$$F(\mu)=\frac{1}{2}\sum_{s=1}^{\infty}\frac{2s+1}{s}P_{s,1}(\mu) \tag{8}$$

To sum this series, we use the relation

$$(2n+1)\sin\theta\cdot P_{n,1}=n(n+1)(P_{n-1}-P_{n+1})$$

[see [1], formula (52a), p. 623, $m=1$]. Equation (8) then becomes

$$F(\mu)=(1/2\sin\theta)[2\sum_{0}^{\infty}P_s(\mu)+P_1(\mu)]$$

$$=(1/2\sin\theta)[2(2-2\mu)^{-1/2}+\mu]$$

$$=(1/2\sin\theta)(\csc\theta/2+\cos\theta)$$

since $\sum_{0}^{\infty} P_s(\mu)=\lim_{p\to 1}\sum_{0} P_s(\mu)p^s=\lim_{p\to 1}(1-2p\mu+p^2)^{-1/2}$. This immediately leads to (1), with $G(\theta)=F(\theta)\sin\theta$.

If the potential field should contain a part due to sources outside the Earth and if the decomposition of the X-component be known, that is $X=X_e+X_i$, then it can be shown in a manner similar to the above that

$$Z_i=\int_0^{\pi}(1/2)(\csc\theta/2+\cos\theta)\cdot\overline{X}_i\cdot\mathrm{d}\theta$$

$$Z_e=\int_0^{\pi}(1/2)(\csc\theta/2-1)\overline{X}_e\cdot\mathrm{d}\theta$$

where the subscripts i and e denote the part due to internal sources and that due to external sources, respectively.

(B) *Trial computation of Z for the eccentric-dipole field*—J. Bartels [2] has drawn H and D world-charts of the "eccentric-dipole" field, which is a potential field originating in the interior of the Earth, and is an approximation to the Earth's main field. An attempt was made to use them to test the above formula for Z. Such a trial computation would, in addition, develop the procedures needed for its large-scale applications.

The point P for $\theta=90°$, $\phi=180°$ (in mid-Pacific Ocean) was chosen for the computation of the Z-value. For the integration a network of parallels and meridians was used taken about P as pole, at steps of $\theta=20°$, $\phi=20°$. In order to obtain the H and D values at the intersections of this network it was necessary to find the coordinates of these points relative to the geographical pole. This was done by means of a set of transformation tables prepared by E. H. Vestine and enlarged by E. Crow and N. Davids, which solve the spherical triangle needed for the transformation. The H- and D-values were then read from their Mercator charts. Note that it is not necessary to draw the network on the charts. Note also that the D-values must be transformed and referred to P as pole.

The results of the computation give $Z(P)=-54.5$ milligauss, while Bartels' value is -56 milligauss. The discrepancy is within the average error made in reading the charts and in the computations. Because of the additive character of the operations it is not likely that this error will increase for larger values of Z. A group of computations can conveniently be handled by two operators, one to read coordinates and record values, the other to read the charts.

An estimate can be made of the contribution of any possible external part of the field by computing Z at a point where its value is well known, say, in the United States. The discrepancy, after allowing for the errors made in the process of computation, may then be due to the external part of the field.

The above formulas could be used as a test for consistency of a Z-chart already drawn with the corresponding H- and D-charts. Computations of Z at several points on the Earth could be made to correct badly drawn contour-lines or uncertain Z-values.

The contribution arising from the external part of the field is discussed by J. H. Taylor in the preceding paper [pp. 223-237].

Thanks are due to E. H. Vestine and J. A. Fleming for their encouragement and constructive criticisms.

References

[1] S. Chapman and J. Bartels, Geomagnetism, Oxford, Clarendon Press (1940).
[2] J. Bartels, Terr. Mag., **41**, 232-250 (1936).

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington 15, D. C., October 31, 1944

A TABLE OF SECULAR VARIATIONS OF THE SOLAR CYCLE

By W. Gleissberg

The aim of the present paper is to provide workers on phenomena which are allied to solar activity with a new table on sunspot-frequency in addition to the tables published by Brunner in the September 1939 issue of this Journal. Brunner's Table 1, which contains the observed relative sunspot-numbers for all months from January, 1749, to December, 1938, shows that the variations of the spot-frequency through the eleven-year cycle are disturbed by secondary short variations. On the assumption that these short variations are of an accidental character (this assumption is supported by the fact that investigations of the curve of observed spot-numbers by periodogram-analysis have revealed no persistent periods shorter than the eleven-year cycle), they can be eliminated by smoothing the observed spot-numbers. The method of smoothing used by the Zürich astronomers consists in forming the average of every 12 consecutive values of the observed monthly relative numbers and in taking the average of two consecutive averages; this latter is taken as smoothed relative sunspot-number for the central of the 13 consecutive months whose observed sunspot-numbers have been used for forming the average. If, for example, A denotes the

Table 1—*Secularly smoothed minima and maxima of sunspots*

Minima				Maxima				Phase-interval	
Epoch	Weight	$(m-m)$	r	Epoch	Weight	$(M-M)$	R	$(M-m)$	$(m-M)$
		years				years		years	years
1632.7	8	....	....	1638.1	8	....	....	5.4	6.0
1644.1	8	11.4	....	1649.8	6	11.7	....	5.7	5.9
1655.7	8	11.6	....	1661.6	6	11.8	....	5.9	5.3
1666.9	7	11.2	....	1672.8	6	11.2	....	5.9	5.1
1677.9	8	11.0	....	1683.9	7	11.1	....	6.0	5.1
1689.0	7	11.1	....	1695.0	8	11.1	....	6.0	5.1
1700.1	8	11.1	....	1705.7	10	10.7	....	5.6	5.6
1711.3	8	11.2	....	1716.8	15	11.1	....	5.5	6.0
1722.8	9	11.5	....	1728.1	16	11.3	....	5.3	5.9
1734.0	10	11.2	....	1739.1	17	11.0	....	5.1	5.7
1744.8	12	10.8	....	1749.8	18	10.7	....	5.0	5.6
1755.4	16	10.6	....	1760.0	27	10.2	....	4.6	5.5
1765.5	25	10.1	....	1769.7	28	9.7	119.4	4.2	6.2
1775.9	25	10.4	8.4	1779.9	24	10.2	120.8	4.0	6.9
1786.8	27	10.9	6.4	1791.2	23	11.3	107.8	4.4	7.0
1798.2	29	11.4	4.1	1803.5	25	12.3	88.6	5.3	6.9
1810.4	38	12.2	2.9	1816.0	31	12.5	78.4	5.6	6.2
1822.2	42	11.8	3.6	1827.5	40	11.5	89.4	5.3	6.0
1833.5	45	11.3	4.9	1838.4	45	10.9	105.9	4.9	6.3
1844.7	46	11.2	5.9	1848.9	46	10.5	120.6	4.2	6.9
1855.8	46	11.1	5.9	1859.8	46	10.9	120.2	4.0	7.4
1867.2	46	11.4	4.6	1871.4	46	11.6	105.7	4.2	7.2
1878.6	46	11.4	3.8	1883.0	46	11.6	96.0	4.4	7.1
1890.1	46	11.5	3.3	1894.8	46	11.8	87.4	4.7	6.7
1901.5	46	11.4	3.2	1906.2	46	11.4	83.5	4.7	6.5
1912.7	46	11.2	3.5	1917.2	46	11.0	87.8	4.5	....

average of the observed monthly relative numbers from January, 1930, to December, 1930, and B the corresponding average from February, 1930, to January, 1931, then $[(A+B)/2]$ is taken as smoothed relative sunspot-number for July, 1930. The smoothed sunspot-numbers as computed by this method have been given in Brunner's Table 2.

Recent investigations have led to the conclusion that—as the course of spot-frequency during each spot-cycle is disturbed by short variations of an accidental character—the cycles themselves seem to be disturbed also by accidental variations. It must, therefore, be possible to reveal the essential behavior of the sunspot-cycles by smoothing them adequately. For this purpose I have formed the averages of every four consecutive epochs of sunspot-minima or maxima as given in Brunner's Table 3 and then I have taken the average of two consecutive averages; this latter is taken as smoothed epoch of minimum or maximum, respectively, for the central of the five consecutive cycles whose epochs of minimum or maximum have been used for forming the average. The same procedure was applied to the smallest relative numbers r which characterize the depths of the minima and to the greatest relative numbers R which characterize the heights of the maxima. The values obtained by this smoothing are given in accompanying Table 1. To avoid any confusion with the smoothed relative sunspot-numbers as computed by the Zürich astronomers I propose to call this new kind of smoothing "secular smoothing."

The arrangement of Table 1 is exactly the same as that of Brunner's Table 3 so that it needs no explanation. The unit of weight of the epochs of minimum and maximum has likewise not been changed. As the weights of the epochs have increased by the secular smoothing I give the phase-intervals also for cycles before 1755.

In Table 1 the secular variations of the solar cycle show themselves by systematic fluctuations of the intervals between two minima $(m-m)$, between two maxima $(M-M)$, from minimum to maximum $(M-m)$ or from maximum to minimum $(m-M)$, and of the quantities r and R which characterize the depths of secularly smoothed minima and the heights of secularly smoothed maxima. The quantities r and R are known, however, only for the more recent cycles. It would be of interest to learn whether the secular variations of the solar cycle are reproduced also in terrestrial phenomena.

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SUMMARY OF THE YEAR'S WORK, TO JUNE 30, 1944, DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON

By J. A. Fleming

Geomagnetic progress during the year July 1, 1943, to June 30, 1944, even though practically all the men of the staff were engaged in war problems, was good. This is attributable to the fact that many of these problems required research utilizing the wealth of observational, theoretical, and instrumental material already in hand through the work and compilations of the Department during 40 years.

Of the ten nonprofit contracts undertaken by the Carnegie Institution of Washington in this Department and still active June 30, 1943, one with the Office of Scientific Research and Development, three with the National Defense Research Committee, and one with the United States Navy were successfully concluded. Continuing or extended nonprofit contracts include two with the National Defense Research Committee, two with the United States Navy, and one with the United States Army. Two new nonprofit contracts were made with the United States Navy—one for the Naval Research Medical Center and one for the Naval Hospital—and two more were arranged to begin after July 1, 1944, one of these with the United States Navy for its Naval Hospital and one with the United States Public Health Service for its National Institute of Health.

These contractual obligations require 95 per cent of the services of the available full-time and part-time regular staff of 71 in Washington and at the observatories. The services so rendered without charge during this report-year to the Government aggregated some 25,550 hours for the scientific staff and 4,050 for the administrative staff; corresponding totals during August 1940 through June 1944 were 116,500 and 20,600, respectively. One hundred and seventy-six temporary employees (including physicists, engineers, mathematicians, computers, machinists, clerks, and guards) were necessary, and the total peak-number of all persons at the Department during the year was 247. Besides these, 13 of our regular and two of our temporary personnel are on leaves of absence either in the armed services or in war agencies of the Government.

The development of these projects as regards temporary personnel was again made possible by the action of universities and individual organizations through the generous granting of leaves of absence and provision of technical advice. We are indebted to many Selective Service Boards for their thoughtful consideration of the urgent need of deferments for many of the professional men coming within the draft age.

Geomagnetic investigations—The variation with geographic position of the amplitude of the solar daily variation (S_q), particularly for the anomalous regions between the geomagnetic and geographic equators, was mapped using observations of S_q obtained by numerous field-stations as well as by more sparsely distributed magnetic observatories. The amplitude of S_q is greatest near the geomagnetic equator and its anomalous increase is the more marked at the points of greatest de-

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parture of the geomagnetic from the geographic equator, in good agreement with the interpretation by McNish of the dynamo-theory of S_q due to Balfour-Stewart and Chapman.

Using the method of field-analysis by integrals, theoretical computations of vertical intensity from world-charts of horizontal intensity and magnetic declination were developed and tested. Relationships were obtained among derived and intrinsic magnetic elements of world-charts in horizontal intensity and declination useful in certain features of the construction of isomagnetic charts consistent with requirements of electromagnetic theory. Maps of magnetic anomalies in certain geographical regions are in preparation and several for strategic areas were completed.

Valuable studies were made of the changes in magnitude of short-period geomagnetic fluctuations at various ocean-depths, because of electromagnetic induction in sea-water. Data on the geomagnetic effects accompanying lightning-discharges were also collected during a two-year period for the magnetic observatories at Huancayo and Watheroo. In this work was also calculated successfully the general shielding-effect of sea-water for these very rapid magnetic fluctuations.

The results of magnetic surveys at stations on land and sea were assembled through 1943. Among these were the records of two Arctic expeditions (Boyd-National Bureau of Standards Expedition of 1941 to Greenland, Baffin Island, and Labrador, and special expedition of 1943 to Greenland and Labrador).

Tables applicable in a world-wide sense in the reduction of magnetic observations to epoch were extended to include the years 1942 and 1943. The reduction of field-observations to epoch for over 10,000 stations on land and sea is now about two-thirds complete.

The geographic incidence of aurora and geomagnetic disturbance was studied, using data for over 100 auroral stations observing since 1872 in the Northern Hemisphere. The isochasms of Fritz were revised, using geomagnetic as well as auroral data, and extended to include quantitative results for the auroral zone and the regions within. Isolines of equal percentage-frequency of days of visually observed aurora were prepared for the Northern Hemisphere for days of observation uninfluenced by unfavorable conditions due to daylight and cloudiness. The improved estimate, using geomagnetic data, of the position of the region of maximum auroral frequency was checked to be in good agreement with extensive auroral observations of the First and Second International Polar Years of 1882-83 and 1932-33, and those of many expeditions in other years. As expected, the world-wide incidence of aurora shows a distribution in close agreement with that for geomagnetic disturbance.

Near the center of the auroral zone, as in middle latitudes, there is marked parallelism in auroral frequency with sunspot-number; at the auroral zone the daily frequency of visually observed aurora is practically independent of sunspot-number. Isochasms for sunspot-maximum and sunspot-minimum are in preparation.

Auroral data for the Southern Hemisphere were also compiled and the position of the southern auroral zone estimated using the geomagnetic data of various expeditions.

The hourly percentage-frequency of aurora in the absence of clouds

and other conditions unfavorable for observation was derived for some 30 stations. These data, contrary to certain previous findings, when arranged on as strictly intercomparable bases as seems conveniently possible, show a fairly simple pattern for the geographic distribution of characteristics of the diurnal variation of aurora. Lines of equal average hourly percentage-frequency of aurora are being mapped for the Northern Hemisphere for several positions of the Sun relative to the Earth.

A study was made of unusual auroral forms observed visually during 1932-33 at Meanook, Canada. It was concluded that long, thin, feeble, homogeneous auroral arcs, previously rarely observed in northern Europe, and of which six cases were noted at Meanook, appear most frequently and perhaps always only in a region some hundreds of kilometers outside the auroral zone. An arc of this type underwent pulsations in light-intensity of period similar to that of simultaneously recorded geomagnetic pulsations.

Six very regular sinusoidal geomagnetic pulsations of period about one minute and amplitude of a few gammas were observed with special equipment at Turtle Mound, Florida, during two weeks of operation. These pulsations of type previously occasionally noted near the auroral zone hence also appear in middle latitudes, where they may appear much reduced in average amplitude.

The analyses of cosmic data continued to increase solar, geomagnetic, ionospheric, and auroral correlations. The results of last year were further confirmed and the operational value of the conclusions regarding the effects of ionospheric and geomagnetic disturbances on conditions of radio transmission and reception was demonstrated.

A close qualitative correlation was identified between the intensity of auroral displays at Ithaca, New York, and rapid changes in horizontal intensity at Huancayo during the larger storms of the past few years; this was done in cooperation with Dr. C. W. Gartlein, of Cornell University. Abrupt maxima of aurora recorded on a photoelectric photometer (designed by Dr. Gartlein with the financial assistance of the National Geographic Society) correspond within one or two minutes, in a high percentage of cases, to the most prominent feature of the geomagnetic disturbance—usually a rapid decrease in horizontal intensity.

The Department undertook, upon request, to serve as a clearing house for observations of sunspots by many American observers pending re-establishment of communication with the international center for such data at Zürich, Switzerland. The material collected is made available to interested governments and private laboratories. Analyses of magnetic and ionospheric conditions coincident with outstanding solar activity are enhanced by the more complete solar data thus immediately available.

Four portable magnetographs were completed and tests undertaken at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey preliminary to assignment for field-use. Improvements were made in the visual recording magnetograph—of which two are now in use.

Terrestrial electricity—An investigation was made of some aspects of

mechanisms proposed to elucidate the generation of charge in the thunder-storm. Quantitative examination brings into question essential portions of all those proposals which have not yet been definitely refuted by qualitative evidence. Certain gaps in the array of information which is required to prove or disprove a proposed mechanism, and reasons for regarding the missing information important, were indicated.

The electric cycle of the thunder-storm may be regarded as consisting of the following steps: (*a*) The initial small-scale separation of charge in which individual particles of precipitation and cloud-particles become charged, and, during which ions (submicroscopic particles, or particles of about molecular size, with one element of charge) may possibly be formed in the electrically active center of the storm-cloud. (*b*) The large-scale separation of charge in which particles or ions charged with electricity of one sign are separated from those of the other sign to distances of several kilometers; this may consist of several steps. (*c*) The initiation of the lightning-discharge, namely, the mobilization of the charges on individual drops, widely distributed throughout some cubic kilometers of space, at such a rate and in sufficient quantity to supply the lightning-discharge proper. (*d*) The lightning-discharge comprising several identifiable steps which follow the foregoing stage and complete the electric cycle. This last phase of the cycle is now much more clearly elucidated than the other steps. Steps (*a*), (*b*), and (*c*) were the subject of this study, from which the following tentative views were developed: (1) That the initial separation occurs in a region of turbulence between two air-masses or air-cells; (2) that a first stage in the large-scale separation (an intermediate-scale separation) consists of a centrifuge-like action of the eddies in the turbulent region; and (3) that after this intermediate-scale separation, charges of one sign and size are introduced into an air-stream having a velocity which may differ in both magnitude and direction from that into which the particles of opposite sign, and doubtless different size, have been introduced. This sequence of processes would apparently be more responsive to windiness and would apparently be capable of separating charge at a considerably greater rate than is possible in a straight wind.

Added analyses of the data from observatories, particularly Watheroo, Huancayo, and College, led to satisfactory conclusions regarding several characteristic aspects of the diurnal variations of atmospheric electricity as well as the variations in amount of radioactive matter and of the number of condensation-nuclei in the atmosphere. The relation between recombination-coefficient and the mobility of ions was determined and a formula established.

The reduction of earth-current records, interrupted because of diversion of personnel to war work, was resumed in December. Final reduction of the Tucson earth-current records from July, 1940, to February, 1943, and the compilation of monthly and yearly averages for the full 11.5-year period of registration at that place, have been completed. The earth-current data from Watheroo and Huancayo have also been brought up to date by reduction of the records from July, 1940, to January, 1944. The most pronounced feature of the records obtained during this interval at all three observatories is the low activity in earth-current flow, characteristic of periods near a sunspot-minimum.

Further study is being made of the seasonal changes in the diurnal variation of earth-current potential-gradient recorded at Tucson. The seasonal variation at this station exhibits several unusual features, most striking of which is a large increase in the magnitudes of both components in January. Records from the individual years have shown that the magnitude of the diurnal variation in January is invariably much greater than that in December or in February and is even equal to, or greater than, that in the summer or equinoctial months. At the same time the character of the diurnal variation and its phase-relationship is the same as that of the other winter months. With the data from all 12 winter seasons during which the Tucson lines were in operation it is possible to follow this increase in activity over five- or ten-day intervals. The increase is found to begin near the winter solstice, to reach its maximum between January 5 and 10, and to disappear early in February. The cause of this unusual feature is not yet clear, but since a similar phenomenon has been noted in the magnetic variations at Tucson, it is unlikely that it is due to changes in resistivity or to other factors which might affect current-flow alone. In this connection it is hoped that direct comparison of the earth-current and magnetic data will be enlightening.

Ionosphere—Activities of the Ionospheric Section were devoted exclusively to war applications. Important contributions leading to improvements of radio-communication circuits resulted from the continued operation of ionospheric recorders at Huancayo, Watheroo, and College, plus the installation of four additional instruments at other sites outside the continental United States.

We are realizing more than ever before the fundamental and binding ties between the ionosphere and the Earth's magnetic field. Individual bits of knowledge gathered from studies of solar activity, aurora, radio blackouts, absorption-measurements, signal-intensities, current-systems, magnetic bays, and many other geophysical factors are gradually being sifted into the proper perspective to provide answers to some of the perplexing problems confronting the geophysicist.

Nuclear physics—The 60-inch cyclotron was completed in December, 1943, and thus the need for an operating equipment of this type in the region of Washington was met. For the time being the extensive research-program in nuclear physics must await the more urgent need of making products radioactivated with the equipment useful in the emergency. It may be stated, however, that the work under way will furnish many data of great future value in those researches.

Observatory- and field-work—The complete geomagnetic, atmospheric-electric, ionospheric, seismic, and meteorological programs were maintained at the Watheroo, Huancayo, and College magnetic observatories. Special studies relating to geomagnetic, atmospheric-electric, and ionospheric problems were made by the staffs at each observatory. The atmospheric-electric program in cooperation with the United States Coast and Geodetic Survey at its Tucson Magnetic Observatory was continued. We were privileged to have active cooperation with seven observatories abroad.

Maintenance of International Magnetic Standards at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic

Survey was effected through the Division of Geomagnetism and Seismology of the Survey.

While no field-work other than at the observatories could be undertaken, it was possible to assist various Governments through loans of magnetic instruments to undertake new magnetic surveys and to obtain repeat-observations at established stations.

Table 1—*Annual values of the magnetic elements at the Watheroo and Huancayo magnetic observatories as based on magnetograms for all days, 1942 and 1943*

Year	Declination, D	Inclination, I	Intensity-components: Horizontal, H	North-south, X	East-west, Y	Vertical, Z	Total, F	Local magnetic constant, G
	° ′	° ′	γ	γ	γ	γ	γ	
			Watheroo Magnetic Observatory					
1942	3 08.2 W	64 24.8 S	24705	24668	−1352	−51593	57203	35718
1943	3 04.4 W	64 25.4 S	24718	24682	−1325	−51643	57254	35745
			Huancayo Magnetic Observatory					
1942	6 45.3 E	2 12.5 N	29438	29234	3463	1135	29460	29443
1943	6 40.0 E	2 11.5 N	29400	29201	3413	1125	29422	29405

Publications—Ten volumes in the special series "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929, under command of Captain J. P. Ault" have now been prepared for off-set printing; of these seven have been published. The volumes are generally classified as Biology (5 volumes), Meteorology (2 volumes), Oceanography (2 volumes, of which one is in two parts, and a third still to be prepared), Chemistry (1 volume). It is necessary to prepare a twelfth and final volume to include general miscellaneous results and reports bearing on oceanography and recommendations based on experience on the *Carnegie*, for the use of other organizations taking up general programs at sea along like lines.

The total of individual papers by members of the Department on December 31, 1943, was 2,267 –50 papers were published during 1943. Since the beginning of the war the usual distribution of reprints to the list of interested investigators and institutions has been limited by necessary postal restrictions. Upon reestablishment of mailing facilities the forwarding of reprints to our colleagues abroad will be made. Meanwhile a sufficient number is held in reserve.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington 15, D. C., September 30, 1944

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS

By J. A. Fleming

This Committee (consisting of Walter S. Adams, J. A. Fleming, and Fred E. Wright) appointed in December, 1932, by Dr. J. C. Merriam, at that time President of the Carnegie Institution of Washington, to consider coordination of continued support by the Carnegie Institution of Washington of research on cosmic rays, continued its activities on a somewhat reduced scale during the year ended June 30, 1944. Despite the assignment of the interested personnel to war-research problems, good progress was made by several of the groups with which the Institution has cooperated.

The operation of cosmic-ray meters at Cheltenham, Huancayo, Teoloyucan, Christchurch, and Godhavn was maintained, almost without interruption by the collaborating agencies. The supplying of recording paper, replacement of batteries and parts, and filing and copying of records to make them promptly available for any current and future use were effected by the Department of Terrestrial Magnetism.

The program of Professor A. H. Compton's group at the University of Chicago included cosmic-ray studies at Echo Lake and on the summit of Mt. Evans. Measurements of the penetration and shower-production of cosmic-ray particles in the energy-range below 2×10^8 electron-volts indicated that many of these particles traversed three lead plates in succession without producing any showers in the lead. Since their majority showed electronic tracks in the cloud-chamber, it is concluded that these particles must have a mass intermediate between that of the electron and that of a mesotron, their mass being roughly estimated to about 20 electronic masses. It is further assumed that this new particle is unstable and disintegrates spontaneously into electrons and neutrinos.

In a series of experiments on the production of mesotrons in different materials, a production of single mesotrons by non-ionizing radiation was found to be present in paraffin, aluminum, iron, and lead. The cross-section of this process is nearly equal to the area of the corresponding atomic nucleus, and it is therefore concluded that the creation of a mesotron is a nuclear process.

The nature of the mesotron-producing radiation was investigated and it was found that most of the mesotrons on Mt. Evans are produced by non-ionizing rays which are very absorbable in one cm of lead but are capable of penetrating as much as 60 cm of paraffin, thus definitely indicating that in the lower atmosphere the mesotrons are produced by photons.

A new method of investigating extensive atmospheric showers, that of measuring the coincidences between cosmic-ray bursts which occur simultaneously in two unshielded ionization-chambers, was put in use. It was found that some of the showers covered the area of 100 square meters with a minimum density of 6,000 particles per square meter. Such showers must originate from primaries having energies as high

as 10^{17} electron-volts, which represents the highest energy so far observed. In many cases showers were found with their cores (high-density regions) extending from one to two meters from the center of the shower. This is 30 times smaller than predicted by the theory for showers initiated by primary electrons. On the basis of current theories the presence of these very narrow showers can only be explained by assuming that they originate from secondary electrons or photons which are produced not too far above the point of observation. However, the mechanism by which such high-energy electrons and photons could be produced is not known in physics so far.

A study of the multiple production of mesotrons in paraffin in the high atmosphere showed that in a block of paraffin of five-cm thickness multiple mesotrons are frequently produced by ionizing primaries (protons)—a result not in agreement with predictions of recently developed theory.

For measuring the frequency of giant atmospheric showers in the stratosphere, a balloon-apparatus of large dimensions was constructed. The results show that very few high-density showers of large extension are present in the stratosphere.

Results of other investigations indicate that some of the showers at sea-level contain electrons of energies as high as 10^{11} electron-volts. Measurements of the coincidences between bursts occurring simultaneously in two unshielded ionization-chambers indicated a considerably smaller number of burst-coincidences at sea-level than at the altitude of 10,600 feet.

It is now well established that mesotrons moving through the Earth's atmosphere disintegrate spontaneously into electrons and neutral particles of unknown nature (possibly neutrinos). The spectrum of the electron arising from the disintegration of these mesotrons was calculated and the theoretical spectrum of the electron was determined for an altitude of 14,200 feet (Mt. Evans), and the results were compared with experimental data obtained on Mt. Evans and in California. The agreement between theory and experiment is satisfactory in both cases. It can therefore be concluded that the electrons in the lower atmosphere are secondaries of the mesotron.

The full-time engagement of S. E. Forbush and Miss Isabelle Lange, of the Department of Terrestrial Magnetism, on defense work permitted only routine handling of records and making copies of data received for distribution to interested investigators.

Professor Victor F. Hess and his associates at Fordham University continued their study of the ionization of the atmosphere of cosmic and terrestrial radiation.

At the New York University, Professor S. A. Korff and collaborators made a study of the quenching mechanism in self-quenching counters. A theory describing the quenching mechanism in self-quenching counters was evolved and was found to be supported by experimental tests. It suggests that the quenching action is due to two phenomena, produced by the organic molecules. The first effect occurs because the ionization-potential of the organic quenching constituent is lower than that of the inert gases used. Consequently, electron-transfer takes place, and the positive ions reaching the cylinder are entirely those of the organic

molecules. Secondly, these organic ions upon neutralization predissociate rather than radiate, because in the complex molecule the energy in the molecular bond is less than that involved in the electronic transitions. Since the molecules do not radiate, no photo-electrons are formed, and with the supply of secondary electrons thus cut off the discharge ceases and the counter is said to be quenched. Experimental tests lent support to this hypothesis.

A mathematical analysis of the correlation between the observed fluctuation in the cosmic-ray intensity at sea-level and the meteorological variables throughout the atmosphere has been made. The actual correlations made with the aid of this analysis by comparing observed cosmic-ray data with information on weather per radiosonde were found to be more significant than were the correlations of the same data when computed according to the older methods in common use. An improved cosmic-ray telescope is under construction to enable further data to be obtained.

Dr. Robert A. Millikan and his associates at the California Institute of Technology were prevented by war responsibilities from making much needed and long-planned measurements with a vertically arranged pair of counters, at or near the predicted latitude of first vertical entrance of the helium-annihilation rays. Nevertheless, time was found to make a careful study and analysis of as yet unpublished data taken in the summer of 1940 by means of high-altitude flights with electroscope. Some new facts and new elements of interpretation were obtained as follows: (1) Evidence for helium-annihilation rays entering between magnetic latitudes 51°.3 and 56°. (2) The possible composite character of the silicon and oxygen bands. (3) The variability in incoming cosmic-ray intensities. (4) A new and more accurate determination of the value of the field sensitive and the non-field sensitive components of the incoming cosmic rays.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington 15, D. C., September 30, 1944

REVIEWS AND ABSTRACTS

(See also pages 269 and 275)

S. L. TING AND S. T. LIN. *A magnetometer for the determination of the vertical component of the Earth's magnetic field.* Rev. Sci. Instr., **15**, No. 7, 171-177 (1944).

The magnetometer consists mainly of two parts: (1) A Helmholtz-Gaugain coil fixed on a horizontal divided circle for producing a uniform vertical magnetic field to balance the vertical component of the Earth's field; (2) a magnet-balance system for observing the effect of the fields. The vertical component of the Earth's field is determined in terms of the coil-constants and the strength of the current passing through the coil. The error due to the horizontal component of the Earth's field and that due to the deviation of the center of gravity of the balance-system from the rotating axis are eliminated, respectively, by taking the mean value of two observations with the axis of the balance set first in one direction and then turned into the opposite direction by rotating the whole instrument through 180° about a vertical axis, and by reversing the polarity of the balance. The special features of the instrument are as follows: (1) A pair of small solenoids is fixed inside the balance-chamber and the balance can have its polarity reversed in its arrested position without being taken out; (2) by providing another pair of horizontal coils on the chamber, the magnetometer serves at the same time as a galvanometer with the magnet balance as its moving magnet (the galvanometer is needed for the determination of the current and would otherwise be provided separately). By preliminary tests the instrument is found to give consistent results. Its sensitivity is about 0′.5 per gamma.

AUTHORS

H. W. NEWTON: *Solar flares and magnetic storms* (Second paper). London, Mon. Not. R. Astr. Soc., **104**, No. 1, 4-12 (1944).

Mr. H. W. Newton has continued his work on this subject, discussing the relationship between the less intense flares and geomagnetic activity. The most intense flares of all are denoted by 3+, and, as his earlier paper showed, these proved to be of great importance in the occurrence of great magnetic storms. The present paper is restricted to flares of intensity 3 and 2 in decreasing order of magnitude, and the data for these less-intense flares are almost entirely from the present 11-year solar cycle. Flares of intensity 3 and 2, during 1934-42, are compared with magnetic storms recorded at Greenwich (Abinger), and also with the daily international magnetic character-figures (De Bilt). The subject is discussed very fully and is illustrated with the aid of a number of diagrams. In the case of flares of intensity 3, there is a small statistical rise of geomagnetic activity within a few days of the mean flare, but in individual cases the disturbance is generally less intense and is less probable than for flares of 3+. In the case of flares of intensity 2, less than two out of ten flares are associated with a magnetic storm on the day of the flare or one or two days later. This result is very little more than can be expected from pure chance. Fade-outs and magnetic activity are dealt with towards the end of the paper, and the percentage-frequency of magnetic storms is plotted against the time-interval in days from fade-out. In a general way the radio fade-out data confirm a small statistical rise of geomagnetic activity within a few days after the mean fade-out. These results are, however, less definite than those from the solar flare data.

From *Nature*, **154**, p. 252, August 19, 1944

P. J. NOLAN and R. I. GALT: *The equilibrium of small ions and nuclei.* R. Irish Acad., A, **50**, No. 5, 51-68 (1944).

An experimental test, using the well-known Schweidler method I, is made of the equilibrium-equation $q=\alpha n^2+bZn$ where n is the number per unit-volume of small ions, q the rate at which they are produced per unit-volume, α the recombination-coefficient for these ions, and Z the number per unit-volume of condensation-nuclei. The object of these tests was to verify the above relationship and to determine the value of the coefficient b. The values of α determined from the data are reasonably constant and agree roughly with that determined for pure air (1.41×10^{-6}). The value of the coefficient b increases with the age of the nuclei and is smaller for positive than for the negative small ions. For atmospheric nuclei aged 0 to 3 hours the value of b is equal to 3.4 and 4.3×10^{-6}, respectively, for the positive and negative small ion. After an interval of 48 hours the values increased to 8.4 and 9.2×10^{-6}, respectively. On the basis of certain assumptions values for the combination-coefficients between charged nuclei and small ions are computed. The authors consider the possible existence of multiple charged nuclei.

G. R. WAIT

MEAN K-INDICES FROM TWENTY-SEVEN MAGNETIC OBSERVATORIES AND PRELIMINARY INTERNATIONAL CHARACTER-FIGURES FOR 1943

By H. F. Johnston

K-indices have been received at the Department of Terrestrial Magnetism from 30 magnetic observatories for the year 1943. Owing to difficulties of communication or stress of other scientific activities due to the world conflict, the records are not complete from all. Those contributing were, in order of geomagnetic latitude: Godhavn; Ivigtut; College; Lerwick; Dombås; Meanook; Sitka; Eskdalemuir; Rude Skov; Agincourt; Witteveen; Abinger; Srednikan; Yakutsk; Cheltenham; Zaimishche; Vyssokaya Dubrava; Zuy; San Fernando; Tucson; Dusheti; Tashkent (Keles); San Juan; Honolulu; Huancayo; Apia; Hermanus; Watheroo; Toolangi; and Amberley. Newly contributing observatories are two from Greenland, six from the Union of Socialist Soviet Republics and Apia, Western Samoa. The lower limit of a K-index of 9 is: 300γ at Tashkent (Keles) and Apia; 350γ at Zuy and Dusheti; 550γ at Srednikan, Yakutsk, Zaimishche, and Vyssokaya Dubrava; 2000γ at Godhavn and Ivigtut.

The mean indices, K_M, for successive three-hour periods of the Greenwich day are given in Table 1 for the year 1943. On the average, 27 observatories contributed to the mean. The agreement of K_M and K_A is very consistent. K_A is the weighted mean index derived from the K-indices (normalized to represent world-wide conditions) received from seven American operated observatories. The difference in monthly sums of K_M and K_A is four per cent on the average, October and December differ by six per cent, due to the increased number of high-latitude stations represented.

The year was comparatively quiet since a K-index of 9 was observed eleven times—once May 1, twice August 8, once August 18 and August 30, five times on August 31, and once on September 30. There was a magnetic storm on August 30-31, disturbances on May 1, August 8, September 29 and 30, and November 19. Disturbances of short duration also occurred on February 17, March 29, and August 18. There was no perfectly calm three-hour interval, though there were three Greenwich days when the value of K_M was 1.0 or less for all eight intervals, namely, January 14, April 24, and December 6.

The mean K-indices by months for the Greenwich day are given in Table 2 and those by years for 1940 to 1943 in Table 3. The mean for the year 1943 is 2.45, which is higher than those for 1940-42 but it must not be taken to indicate an increase in activity for the year since more high-latitude stations are reporting. Reports were not received from Witteveen (after March), Chambon-la-Forêt, Zô-Sè, Kuyper, and Pilar, whereas the large number of six from the U. S. S. R. and two from Greenland supplied indices. The average mean K-indices for the eight intervals of the Greenwich day over the four-year period 1940-43 must be taken as an indication that the activity in the second half of the

Table 1--Mean K-indices from twenty-seven observatories, 1943

Day	January 1943 Values K_M	Sum	February 1943 Values K_M	Sum
1	0.5 0.3 0.5 0.7 0.5 1.7 2.7 2.5	9.4	1.9 0.9 1.4 0.9 1.2 1.7 1.3 2.3	11.6
2	1.6 1.0 1.8 1.6 1.3 2.7 1.7 1.2	12.9	1.3 1.0 1.8 1.3 2.3 2.0 1.2 1.8	12.7
3	1.4 1.5 1.2 1.7 2.9 2.8 2.0 2.7	16.2	2.1 2.3 2.6 2.6 2.7 1.8 2.5 2.5	19.1
4	2.4 2.2 2.4 4.9 5.2 5.2 4.1 3.1	29.5	2.6 3.0 2.4 3.7 2.5 1.8 2.2 2.2	20.4
5	3.6 3.0 3.2 2.7 1.7 3.0 2.6 3.2	23.0	2.5 1.8 2.3 2.6 3.0 2.4 3.1 1.5	19.2
6	2.7 2.0 2.4 2.4 2.0 2.5 2.2 2.1	18.3	2.9 1.2 2.1 2.3 2.4 3.1 2.3 2.5	18.8
7	1.1 0.9 0.8 0.6 0.7 0.7 0.7 1.0	6.5	1.6 1.6 1.4 1.0 0.8 1.5 1.6 2.0	11.5
8	0.6 1.0 0.8 0.7 1.4 1.9 2.2 2.5	11.1	1.6 1.0 1.3 1.2 1.5 1.3 3.0 1.5	12.4
9	2.2 1.9 3.2 2.9 1.0 1.6 1.2 1.1	15.1	1.9 1.8 2.2 1.8 1.2 1.0 1.9 1.2	13.0
10	1.0 1.4 1.5 1.8 1.2 1.4 1.6 2.6	12.5	0.4 0.7 0.8 0.9 1.3 1.5 1.9 1.3	8.8
11	1.3 1.1 1.1 0.9 0.6 1.9 1.0 1.7	9.6	2.7 3.0 3.3 2.2 2.0 0.3 1.2 1.2	15.9
12	1.4 2.2 2.6 1.5 1.4 0.7 1.0 1.6	12.4	1.1 1.3 0.7 1.5 1.4 0.8 1.8 1.8	10.4
13	1.4 1.0 1.3 1.2 0.9 1.2 1.0 1.2	9.2	2.7 2.7 3.6 2.6 2.8 2.2 2.3 1.9	20.8
14	0.6 1.0 1.0 0.5 0.4 0.4 0.6 0.6	5.1	1.9 1.5 1.9 2.3 1.1 0.7 1.1 1.5	12.0
15	0.3 0.8 0.8 0.4 0.9 1.2 0.9 1.2	6.5	1.6 1.1 1.8 2.1 1.3 0.6 1.5 0.8	10.8
16	0.9 0.8 0.9 1.3 2.0 2.7 2.2 1.9	12.7	0.8 0.7 0.8 0.8 0.5 2.3 2.4 1.8	10.1
17	2.7 1.8 2.9 4.3 4.1 4.1 3.5 2.8	26.2	2.9 4.1 4.4 5.7 4.3 3.1 3.9 3.6	32.0
18	2.2 1.9 2.9 2.5 2.6 1.8 2.6 1.1	17.6	2.5 2.6 3.1 2.7 2.8 1.6 0.8 1.9	18.0
19	1.6 1.5 2.0 1.3 2.2 2.4 2.2 2.1	15.3	2.7 1.5 2.5 2.5 2.3 2.7 1.2 1.0	16.4
20	1.6 2.1 3.2 3.0 2.8 5.1 5.5 5.2	28.5	0.5 1.5 0.7 2.2 2.0 2.0 0.9 0.7	10.5
21	3.7 3.2 3.5 4.3 3.9 2.9 2.0 3.9	27.4	0.4 0.3 1.2 1.1 0.8 1.0 1.5 1.1	7.4
22	4.6 1.8 2.7 3.3 4.0 4.2 3.6 3.1	27.3	0.7 0.4 0.9 2.1 1.9 1.1 1.5 1.8	10.4
23	2.8 2.4 2.0 2.5 2.0 1.8 1.6 2.1	17.2	1.6 1.5 2.0 2.1 1.9 1.8 2.7 2.4	16.0
24	2.6 1.8 1.4 2.5 2.2 2.0 2.4 1.9	16.8	2.1 2.3 2.0 2.3 2.1 1.5 1.9 2.2	16.4
25	1.6 1.4 1.6 1.6 1.4 1.2 1.0 0.9	10.7	1.0 1.5 0.4 1.8 1.7 3.2 4.2 3.6	17.4
26	2.3 2.6 3.1 4.0 2.4 3.2 1.6 1.9	21.1	4.2 3.9 2.8 3.3 1.6 3.7 3.8 2.9	26.2
27	1.9 1.0 0.8 2.1 2.9 2.9 1.6 0.8	14.0	3.3 2.9 1.4 2.8 2.2 1.1 1.9 1.6	17.2
28	0.8 1.8 2.2 3.0 2.5 2.8 2.5 1.5	17.1	1.3 1.4 1.1 1.5 0.9 1.0 1.1 0.3	8.6
29	1.5 1.0 1.2 1.5 1.9 1.2 1.7 1.9	11.9		
30	2.8 2.0 1.5 0.9 1.0 0.9 1.0 2.1	12.2		
31	0.9 1.3 1.3 1.2 1.6 2.2 1.5 1.8	11.8		

Day	March 1943 Values K_M	Sum	April 1943 Values K_M	Sum
1	0.6 2.0 0.8 1.3 2.6 2.9 2.0 1.2	13.4	3.2 3.1 2.4 2.8 2.5 2.6 2.8 2.2	21.6
2	1.5 2.2 4.4 3.8 3.3 1.5 1.7 1.4	19.8	3.2 2.2 3.3 1.7 3.3 2.3 1.6 3.0	20.6
3	0.9 1.2 2.2 3.3 2.6 1.6 2.3 2.8	16.9	4.7 3.9 4.1 3.9 3.2 3.8 3.0 3.5	30.1
4	2.4 2.4 3.6 3.7 3.6 2.6 3.2 3.9	25.4	3.5 3.4 2.8 3.3 4.1 3.1 3.9 2.4	26.5
5	2.8 3.3 3.4 2.5 2.3 3.5 2.5 2.2	22.5	4.1 2.7 2.7 3.2 3.0 4.9 2.8 3.8	27.2
6	2.3 1.2 2.0 1.0 1.9 1.8 2.8 1.7	14.7	3.1 2.1 3.5 4.3 4.6 3.8 2.5 3.2	27.1
7	1.9 1.1 1.2 1.2 1.6 1.8 2.2 2.2	13.2	4.1 3.5 2.8 2.7 3.6 2.1 3.0 2.2	24.0
8	2.5 2.5 2.1 2.3 2.1 2.3 1.9 2.3	18.0	2.5 1.7 3.0 2.4 1.6 0.9 1.1 0.8	14.0
9	2.6 1.2 2.2 2.5 2.2 2.0 1.7 2.0	16.4	0.6 1.0 0.6 0.6 1.6 1.0 1.9 1.7	9.0
10	1.6 0.8 0.8 1.2 1.3 1.7 1.3 1.6	10.3	1.2 2.8 3.8 4.1 3.9 2.8 4.1 3.9	26.6
11	2.3 1.3 0.9 1.5 2.2 3.0 4.6 3.3	19.1	4.2 4.8 4.8 4.3 2.5 2.5 3.1 3.0	29.2
12	3.2 3.5 1.8 2.9 3.5 4.2 3.2 2.5	24.8	2.1 0.9 1.1 1.5 1.8 1.1 1.1 0.8	10.4
13	1.8 1.1 0.7 0.6 1.7 0.6 0.8 1.3	8.6	0.4 0.9 1.3 0.6 0.7 1.4 0.5 1.1	6.9
14	2.0 2.5 2.2 2.6 1.8 2.5 0.8 1.2	15.6	0.8 0.7 0.8 0.8 1.0 1.2 1.2 1.0	7.5
15	0.8 0.8 0.7 1.0 0.8 1.7 0.9 1.3	8.0	0.8 1.0 1.6 2.4 2.5 2.5 2.9 2.8	16.5
16	2.0 2.6 3.3 4.9 3.4 2.7 3.7 3.8	26.4	2.5 2.6 3.2 3.2 2.8 2.4 2.5 1.8	21.0
17	3.7 1.2 1.6 3.3 2.9 1.1 0.8 1.9	16.5	1.9 1.5 3.0 2.4 1.8 2.0 1.3 1.5	15.4
18	1.2 1.2 2.4 2.0 1.1 2.2 2.0 1.5	13.6	1.3 2.8 1.9 1.8 1.2 1.4 0.9 1.3	12.6
19	1.2 1.0 2.3 2.3 1.6 3.2 3.2 3.4	18.2	2.0 2.1 0.9 1.2 1.9 0.8 1.2 0.6	10.7
20	2.0 2.6 4.2 4.0 3.1 3.6 4.3 1.6	25.4	0.4 1.2 1.5 2.9 3.1 3.1 1.5 2.4	16.1
21	1.5 1.9 2.3 3.5 2.3 2.5 2.0 1.7	17.7	3.6 3.4 3.2 4.1 3.6 3.1 3.2 1.9	26.1
22	1.8 2.0 1.5 3.2 2.8 3.3 3.8 4.1	22.5	1.3 1.9 3.2 2.9 1.5 1.5 1.0 1.2	14.5
23	4.5 4.1 4.0 3.7 3.3 2.5 3.2 2.4	27.7	0.5 1.0 0.8 1.2 0.7 0.8 0.9 0.9	6.8
24	1.5 1.6 2.7 2.2 3.2 3.1 1.1 0.5	15.9	0.8 0.8 0.6 0.8 0.9 0.6 0.5 1.0	6.0
25	0.8 2.2 1.1 1.0 0.9 0.6 0.6 0.7	7.9	2.2 2.4 2.6 1.9 1.9 2.7 2.6 3.7	20.0
26	1.7 1.4 1.8 0.8 1.0 1.8 1.0 1.7	11.2	4.8 4.4 4.4 3.6 3.0 2.4 2.5 3.2	28.3
27	1.6 0.5 0.7 1.3 1.1 1.7 2.2 1.5	10.6	3.2 1.5 1.6 0.6 2.0 2.0 1.1 0.5	12.5
28	0.3 0.5 1.0 0.9 1.2 0.9 1.8 1.5	8.1	1.1 1.6 1.4 0.6 0.8 1.4 2.7 3.3	12.9
29	2.0 2.1 1.8 2.6 3.2 3.7 5.9 4.8	26.1	2.9 2.0 3.2 2.9 2.2 2.3 2.1 2.5	20.1
30	4.0 3.5 3.1 3.7 3.3 2.8 4.0 3.5	27.9	2.8 3.7 3.2 4.5 3.0 2.2 2.7 2.9	25.0
31	3.3 2.8 2.0 1.4 2.3 3.8 2.8 4.0	22.4		

Table 1--Mean K-indices from twenty-seven observatories, 1943--continued

Day	May 1943 Values K_M	Sum	June 1943 Values K_M	Sum
1	4.0 4.6 4.9 5.0 4.0 3.8 4.4 4.6	35.3	1.7 1.9 2.2 2.5 2.1 1.3 2.4 2.6	16.7
2	4.3 2.9 3.8 4.2 3.3 4.0 2.2 1.9	26.6	1.4 1.5 1.6 3.1 2.9 1.3 1.4 1.0	14.2
3	2.5 1.0 1.1 1.4 2.0 3.2 1.9 3.6	16.7	0.9 0.9 2.1 1.3 1.3 1.3 0.9 1.4	10.1
4	2.3 3.2 2.5 1.7 1.6 1.8 1.9 2.5	17.5	1.6 1.5 1.3 1.2 1.3 0.9 0.5 0.3	8.6
5	1.7 1.4 2.5 2.8 2.8 2.3 1.9 1.5	16.9	1.7 1.1 0.9 1.3 2.0 1.9 2.1 2.2	13.2
6	2.4 0.9 0.5 1.7 1.8 1.9 0.9 0.8	10.9	3.2 3.3 3.3 1.9 2.0 1.4 0.9 1.0	17.0
7	2.1 2.3 1.3 1.1 1.3 0.8 1.0 1.3	11.2	1.3 1.4 1.6 2.8 3.3 2.6 2.0 2.9	17.9
8	1.1 0.8 0.4 0.8 1.3 1.1 1.0 0.7	7.2	2.8 4.0 3.6 4.6 4.0 4.1 3.1 3.3	29.5
9	0.7 1.2 1.4 0.9 0.8 1.0 0.9 0.6	7.5	3.1 3.9 3.7 4.4 3.2 2.8 2.6 2.2	25.9
10	1.0 1.0 1.3 1.8 2.3 2.4 2.1 1.1	13.0	1.6 3.2 3.8 4.3 2.0 3.5 1.8 3.4	23.6
11	1.3 2.0 1.8 0.9 1.8 3.0 2.1 2.4	15.3	1.4 1.0 1.9 3.4 3.5 3.4 2.1 2.5	19.2
12	2.4 3.7 3.3 1.6 1.6 1.2 2.0 1.9	17.7	1.4 2.8 3.7 3.3 3.0 2.2 2.8 2.2	21.4
13	2.1 2.0 4.2 3.6 3.4 3.6 2.0 2.7	23.6	4.8 3.3 2.2 2.4 3.2 2.9 3.2 2.9	24.9
14	3.1 2.8 1.9 3.1 1.7 1.9 1.6 2.6	18.7	3.7 3.3 3.0 3.2 2.6 2.3 1.5 0.8	20.4
15	4.9 4.0 3.6 3.9 2.7 2.1 2.1 2.5	25.8	0.9 1.8 1.4 1.1 0.8 0.6 1.2 1.3	9.1
16	1.0 0.9 1.6 3.5 3.9 3.0 3.5 2.5	19.9	1.1 1.1 1.0 1.0 0.8 0.9 0.9 1.0	7.8
17	2.6 2.6 3.4 2.9 2.5 3.5 4.2 3.9	25.6	1.4 1.1 0.7 0.5 0.6 0.5 0.4 0.4	5.6
18	4.6 4.6 4.6 4.3 3.6 2.8 2.7 3.6	30.8	0.3 0.8 0.9 0.9 0.8 0.8 1.0 1.2	6.7
19	3.5 4.0 3.6 2.3 3.4 2.0 3.1 2.6	24.5	1.2 1.3 1.6 2.8 2.5 3.1 2.6 3.6	18.7
20	2.0 1.3 1.3 2.0 2.3 1.1 1.1 1.3	12.4	4.4 3.7 2.6 3.3 2.8 2.5 2.7 3.3	25.3
21	1.3 1.3 1.7 1.9 1.3 1.4 1.0 0.3	10.2	3.3 2.8 3.2 3.8 3.5 3.6 2.9 3.0	26.1
22	0.7 1.2 1.3 1.1 1.0 0.8 0.4 1.3	7.8	2.7 3.9 4.2 2.9 2.6 2.8 3.0 2.6	24.7
23	1.1 2.3 2.4 2.3 2.1 2.0 2.1 2.5	16.8	3.0 3.2 3.0 2.8 4.1 3.8 3.2 3.5	26.6
24	4.9 3.7 2.6 2.7 3.2 3.6 3.5 3.7	27.9	3.4 4.0 3.9 3.5 3.2 3.6 3.2 2.7	27.5
25	3.7 2.9 3.9 3.1 3.9 2.9 3.0 2.6	26.0	2.9 2.9 3.0 3.2 2.6 2.7 2.5 2.8	22.6
26	2.4 2.1 1.4 1.9 1.7 2.6 2.6 2.5	17.2	1.8 2.0 1.2 1.5 1.8 1.2 1.7 1.9	13.1
27	2.8 3.1 3.0 1.7 1.4 2.2 2.6 3.5	20.3	2.8 1.3 1.7 1.7 1.6 2.0 1.7 3.2	16.0
28	4.1 4.0 3.9 3.7 3.1 3.4 2.9 3.2	28.3	2.5 3.1 4.3 3.1 3.7 2.7 3.6 2.8	25.8
29	2.9 3.6 2.9 2.8 2.1 1.7 2.4 1.5	19.9	2.9 3.0 2.0 1.8 1.0 0.9 1.0 0.8	13.4
30	2.4 2.0 3.3 1.3 1.8 1.7 1.6 1.7	15.8	1.3 1.3 1.3 1.7 1.4 0.9 0.6 0.8	9.3
31	1.2 1.1 1.6 1.5 1.7 1.8 1.5 1.8	12.2		

Day	July 1943 Values K_M	Sum	August 1943 Values K_M	Sum
1	1.1 1.4 1.8 0.7 0.8 0.8 0.8 0.8	8.2	2.8 2.9 3.3 3.0 3.9 3.9 3.3 2.4	25.5
2	0.6 1.1 2.1 1.6 1.5 1.0 1.4 2.5	11.8	2.6 3.1 4.4 3.1 3.5 3.6 3.6 3.2	27.1
3	2.6 4.0 4.0 2.9 2.2 2.1 1.9 1.6	21.3	4.4 3.5 3.9 3.8 3.9 2.4 3.7 2.9	28.5
4	2.0 2.0 2.6 3.8 3.5 4.5 4.4 3.8	26.6	2.7 3.5 3.5 3.6 4.0 3.9 3.7 3.1	28.0
5	4.7 4.6 4.4 3.8 4.1 4.0 4.2 4.1	33.9	4.1 3.3 3.7 3.4 3.6 2.9 2.8 2.2	26.0
6	4.4 4.5 4.1 5.0 3.9 3.7 3.2 3.7	32.5	2.2 2.3 3.5 2.8 2.4 2.6 3.8 2.0	21.6
7	3.2 3.2 2.8 3.3 2.5 3.2 2.5 2.8	23.5	2.2 2.1 3.2 5.1 3.8 3.4 1.0 1.3	22.1
8	3.5 3.2 4.3 4.3 3.6 2.9 2.9 2.0	26.7	2.8 4.1 3.2 4.8 5.3 5.7 5.0 5.3	36.2
9	2.9 3.1 4.8 4.5 3.1 3.7 4.1 3.0	29.2	5.6 4.7 3.6 2.9 3.0 2.9 2.1 3.0	27.8
10	3.2 3.9 3.4 4.4 3.9 3.1 2.3 2.1	26.3	3.2 3.1 2.1 1.9 1.4 1.0 1.2 1.9	15.8
11	2.2 3.4 4.2 3.8 3.9 2.8 2.5 3.0	25.8	2.0 1.7 2.0 1.5 1.2 1.3 1.6 1.7	13.0
12	3.1 3.5 3.5 3.4 2.1 2.7 2.9 2.9	24.1	1.9 1.6 2.2 1.1 1.1 2.1 2.1 3.7	15.8
13	3.5 2.8 2.9 2.5 2.8 3.2 2.9 2.4	23.0	3.0 4.6 4.4 5.1 4.8 3.9 4.4 4.9	35.1
14	2.4 0.6 0.7 1.0 0.8 1.0 1.5 0.6	8.6	3.8 2.9 3.0 3.7 3.8 3.6 3.9 4.1	28.8
15	1.0 1.5 2.2 2.5 2.9 2.4 2.8 2.0	17.3	3.0 2.9 3.0 2.1 3.1 3.3 3.7 3.3	24.4
16	2.6 2.6 2.4 2.2 2.1 2.5 2.5 2.2	19.1	3.6 3.3 4.6 4.9 3.4 3.1 2.8 2.9	28.6
17	3.3 2.0 1.7 1.4 2.2 1.9 2.4 2.9	17.8	4.5 4.1 4.2 3.0 2.3 3.0 2.9 3.2	27.2
18	2.2 3.0 2.8 3.4 4.0 3.6 3.4 3.0	25.4	3.3 3.3 4.2 5.9 4.4 3.6 2.7 1.7	29.1
19	3.3 3.3 3.6 2.0 2.1 2.8 2.4 2.9	22.4	1.5 2.4 4.2 4.4 4.1 4.2 4.0 4.2	29.0
20	2.7 1.8 2.1 2.3 2.1 2.4 1.8 2.0	17.2	4.7 4.1 4.5 4.9 3.9 2.9 3.1 3.6	31.7
21	3.2 2.5 3.2 3.0 2.8 2.9 2.2 2.6	22.4	4.0 4.0 3.6 3.1 3.1 1.7 1.6 2.0	23.1
22	2.4 2.9 3.2 3.3 2.9 2.6 2.5 2.8	22.6	1.7 1.3 1.3 0.7 1.8 1.3 1.6 1.3	11.0
23	1.9 1.8 2.5 2.2 2.0 2.2 1.8 1.4	15.8	1.6 2.0 1.5 1.7 2.5 1.9 2.3 3.2	16.7
24	1.6 2.1 1.7 1.0 1.1 0.9 0.5 0.6	9.5	3.3 4.6 4.3 2.1 2.2 3.6 2.1 2.6	24.8
25	1.0 1.7 1.0 1.1 0.8 0.8 1.1 1.5	9.0	3.6 3.9 3.2 2.6 2.7 3.3 2.6 2.9	24.8
26	1.5 1.5 1.6 2.4 1.3 1.6 2.9 2.1	14.9	2.8 3.3 4.4 3.0 2.3 2.5 2.6 1.8	22.7
27	3.0 1.9 2.2 2.1 2.3 2.2 1.5 1.4	16.6	1.3 1.9 1.0 1.0 1.0 1.1 1.7 1.4	10.4
28	0.8 1.5 1.5 1.6 2.0 1.0 1.3 1.4	11.1	1.6 2.6 2.5 4.1 5.6 4.6 3.2 4.6	28.8
29	1.9 1.6 1.2 0.9 0.6 0.6 0.5 1.6	8.9	4.0 3.6 3.7 4.0 4.8 4.7 3.8 2.4	31.0
30	2.4 3.4 3.2 4.1 3.8 3.9 3.3 2.6	26.7	4.6 5.4 4.8 4.6 5.3 5.3 5.1 5.7	40.8
31	3.0 2.1 2.9 3.9 2.5 1.7 2.5 3.2	21.8	5.8 6.3 6.3 6.0 6.3 5.9 5.0 3.9	45.5

Table 1--Mean K-indices from twenty-seven observatories, 1943--concluded

Day	September 1943 Values K_M		Sum	October 1943 Values K_M		Sum
1	4.6 3.7 3.8 4.0	4.3 4.3 3.9 2.6	31.2	4.2 4.5 3.6 3.7	4.7 3.8 4.0 4.3	32.8
2	4.1 3.6 3.2 4.1	4.6 2.9 3.9 4.0	30.4	4.9 3.5 3.2 4.0	4.5 4.3 4.8 4.1	33.3
3	3.8 4.4 4.5 4.8	4.5 4.1 3.0 4.6	33.7	3.9 3.3 4.6 4.9	4.1 4.2 3.3 4.2	32.5
4	2.9 4.1 4.5 4.4	3.6 3.1 3.1 1.9	27.6	3.8 3.6 3.2 3.8	3.8 3.0 1.9 2.2	25.3
5	3.6 3.9 2.9 3.5	2.6 3.3 3.0 2.9	25.7	3.2 2.2 2.1 1.8	2.0 1.5 2.6 1.8	17.2
6	2.5 2.8 3.0 2.9	1.6 2.1 2.5 0.9	18.3	1.7 2.0 1.6 1.4	1.0 1.3 0.5 0.6	10.1
7	2.3 2.0 1.8 1.9	1.8 1.9 2.0 1.8	15.5	2.6 1.9 1.6 2.3	3.8 3.3 3.2 3.7	22.4
8	2.1 1.8 2.5 2.5	2.3 4.4 4.8 4.0	24.4	3.5 2.0 2.5 5.1	4.5 4.0 3.5 4.1	29.2
9	4.9 4.0 3.5 4.1	3.4 3.1 3.4 4.2	30.6	3.1 4.2 5.2 4.3	3.6 4.5 4.2 3.5	32.6
10	4.6 4.0 3.4 4.4	3.7 3.8 2.5 3.5	29.9	2.5 2.7 3.5 2.3	3.2 4.6 2.4 1.7	22.9
11	3.9 4.0 3.0 2.4	3.6 3.2 2.6 3.6	26.3	1.9 1.4 3.2 3.2	2.8 1.8 2.6 2.7	19.6
12	3.6 2.1 2.2 4.1	2.3 3.0 3.6 2.7	23.6	2.9 3.3 3.3 2.0	0.7 1.9 3.0 2.8	19.9
13	4.0 4.2 2.9 3.9	3.2 3.9 3.6 2.6	28.3	2.4 2.2 1.2 1.1	2.4 1.3 1.2 1.6	13.4
14	3.7 3.2 2.6 4.2	3.5 2.4 3.5 3.6	26.7	1.8 0.8 1.0 1.0	0.8 1.2 2.0 0.6	9.2
15	3.4 2.6 2.9 2.1	2.2 2.9 2.7 3.1	21.9	0.6 0.4 0.6 1.2	1.3 0.4 0.8 0.6	5.9
16	2.1 1.8 1.6 1.7	2.4 3.5 2.5 2.5	18.1	1.1 1.2 1.0 0.8	1.5 1.2 0.8 1.8	9.4
17	2.3 3.2 2.6 1.5	1.6 2.0 2.1 2.8	18.1	1.1 1.8 3.2 3.5	3.2 1.9 1.9 2.7	19.3
18	1.6 2.0 1.2 1.4	0.8 0.6 1.9 3.8	13.3	1.0 0.5 1.2 1.0	1.5 2.5 2.4 2.4	12.5
19	2.8 3.0 2.6 2.8	2.0 1.5 2.0 1.5	18.2	2.1 2.2 2.1 2.5	2.3 1.5 2.0 0.8	15.5
20	1.0 1.5 1.3 1.0	2.6 2.1 1.5 2.8	13.8	1.3 1.2 1.3 1.4	1.8 3.7 4.5 2.8	18.0
21	3.1 2.7 3.4 4.4	3.5 2.6 3.6 2.8	26.1	3.5 2.0 1.8 0.9	0.7 0.6 0.8 0.8	11.1
22	3.2 3.7 3.4 2.6	3.6 3.6 2.2 2.1	24.4	1.0 1.5 3.1 4.6	3.6 3.8 2.8 3.6	24.0
23	2.9 3.1 3.1 2.9	1.6 2.1 1.8 2.1	19.6	3.8 2.0 1.9 1.4	3.2 1.8 1.3 2.5	17.9
24	2.6 1.7 1.9 1.4	1.1 1.2 1.8 1.8	13.5	3.1 2.7 2.9 5.4	4.8 3.9 4.0 3.7	30.5
25	1.6 3.6 3.9 3.0	3.1 2.2 1.0 1.3	19.7	4.5 3.6 4.2 4.0	4.2 3.4 3.9 3.3	31.1
26	1.7 3.3 4.0 3.8	5.4 4.8 4.3 3.8	31.1	4.1 4.5 5.0 5.0	4.8 4.0 3.9 3.4	34.7
27	4.1 3.5 3.4 4.3	3.8 3.2 4.5 3.9	30.7	3.2 3.7 4.3 3.8	2.5 3.1 4.3 4.2	29.1
28	4.9 4.4 4.1 4.1	4.7 3.8 3.6 4.2	33.8	4.5 4.5 3.8 3.8	3.7 4.3 3.8 3.5	31.9
29	3.5 4.3 4.5 5.0	5.4 4.3 5.0 4.3	36.3	3.9 3.8 3.9 4.5	4.6 3.8 4.2 3.4	32.1
30	4.3 5.0 4.2 5.5	4.3 3.8 4.2 5.0	36.3	4.0 3.5 3.9 4.1	5.0 3.7 3.5 4.1	31.8
31				3.4 4.2 3.5 4.7	4.8 3.5 4.1 3.2	31.4

Day	November 1943 Values K_M		Sum	December 1943 Values K_M		Sum
1	2.9 2.7 3.7 4.1	4.5 3.5 3.7 2.1	27.2	0.4 0.6 1.0 1.7	1.9 3.1 2.7 3.0	14.4
2	1.9 1.2 2.2 2.4	0.7 2.0 1.5 0.8	12.7	1.7 2.0 1.8 2.0	2.3 4.6 4.5 3.8	22.7
3	1.3 1.7 1.7 0.5	1.2 0.8 1.2 1.9	10.3	2.9 3.5 3.3 2.3	4.0 4.3 3.9 3.3	27.5
4	1.4 1.6 1.1 1.0	1.6 1.2 1.0 1.9	10.8	3.2 2.7 2.7 2.5	4.0 3.0 3.4 3.6	25.1
5	1.9 2.7 3.0 2.8	3.7 3.0 2.3 1.9	21.3	2.6 3.8 2.7 2.2	3.0 3.0 2.0 1.5	20.8
6	2.0 2.6 2.7 2.2	3.4 5.5 4.2 4.0	26.6	0.9 0.4 0.3 0.6	0.5 0.9 0.3 0.7	4.6
7	3.0 2.2 3.8 3.1	1.5 1.5 3.5 2.7	21.3	1.3 0.7 1.1 2.0	1.9 0.8 0.8 0.6	9.2
8	2.3 3.0 3.5 3.2	1.9 2.3 1.9 2.4	20.5	1.1 1.5 1.1 1.5	1.3 2.2 1.2 0.7	10.6
9	3.0 2.5 3.3 1.1	1.2 1.9 1.9 2.3	17.2	1.7 2.2 2.7 2.3	1.8 2.8 1.8 1.5	16.8
10	2.0 1.3 1.2 1.4	1.4 1.7 3.2 2.5	14.7	2.5 1.1 1.6 2.1	2.8 2.2 1.1 1.1	14.5
11	1.0 1.4 0.9 0.5	0.5 0.5 1.1 0.6	6.5	0.7 0.8 0.6 1.5	1.1 1.0 1.2 0.9	7.8
12	0.6 0.9 1.1 2.5	2.3 1.8 1.2 0.8	11.2	0.7 0.7 0.6 0.8	0.6 1.2 1.6 1.8	8.0
13	0.3 0.4 0.3 0.8	1.0 1.4 1.7 1.8	7.7	2.0 1.0 0.8 0.8	0.7 0.5 2.1 0.9	8.8
14	1.3 1.9 1.5 0.5	0.9 1.5 1.6 0.6	9.8	0.3 0.5 1.2 1.9	3.2 3.5 1.7 1.7	14.0
15	0.7 0.9 0.9 1.0	1.2 1.7 1.9 1.9	10.2	1.5 0.6 1.2 1.0	0.7 1.3 2.4 3.1	11.8
16	2.1 3.2 1.9 1.8	3.0 2.3 2.8 2.6	19.7	3.0 1.8 4.2 4.8	5.2 4.4 3.9 3.7	31.0
17	1.4 0.8 0.8 0.9	0.9 0.8 0.8 1.1	7.5	3.6 3.9 3.3 4.8	4.0 4.5 2.9 3.8	30.8
18	1.2 1.0 1.8 2.3	2.8 3.0 2.4 1.7	16.2	3.7 3.1 3.1 3.3	4.2 3.1 3.7 2.3	26.5
19	1.7 4.0 5.5 5.6	5.2 4.2 3.8 5.0	35.0	3.5 2.7 3.8 4.0	4.2 5.0 4.8 3.8	31.8
20	4.1 4.6 4.4 4.5	3.5 4.6 3.7 2.9	32.3	3.9 2.6 3.3 4.2	4.2 4.4 3.7 4.0	30.3
21	4.7 3.5 3.9 4.4	4.4 4.5 3.8 3.3	32.5	4.0 2.0 1.9 2.5	3.6 2.2 4.1 4.0	24.3
22	2.7 3.5 3.2 2.9	3.6 4.3 2.9 3.2	26.3	3.2 2.6 2.6 3.7	3.0 3.3 3.0 3.3	24.7
23	3.0 3.5 3.6 3.7	4.2 4.5 4.6 4.9	32.0	2.2 2.2 3.1 3.3	3.7 2.0 2.7 2.3	21.5
24	4.0 3.3 3.5 3.6	4.8 4.2 4.4 3.8	31.6	1.9 1.9 2.1 2.2	2.0 1.7 2.3 1.5	15.6
25	3.5 3.3 3.9 4.4	4.2 4.5 5.0 4.2	33.0	1.5 3.3 2.2 3.2	1.2 1.4 2.2 2.3	17.3
26	2.6 3.6 3.8 3.1	5.0 5.5 4.0 4.6	32.2	2.8 1.3 1.6 2.7	3.1 4.0 3.2 2.7	21.4
27	4.5 5.0 4.5 4.2	4.4 2.9 3.8 3.9	33.2	1.2 2.3 1.6 2.1	2.4 1.3 1.4 0.7	13.0
28	3.3 3.1 4.0 4.4	1.8 2.0 3.4 2.7	24.7	1.8 1.3 1.8 0.6	0.7 0.5 0.5 0.5	7.7
29	3.0 3.8 3.9 3.5	3.7 3.2 4.0 1.8	26.9	1.1 1.5 1.7 2.6	1.0 2.4 2.9 1.6	14.8
30	1.6 1.3 2.1 1.7	2.7 3.0 0.7 0.5	13.6	1.0 0.5 1.0 1.0	2.4 1.8 1.0 1.3	10.0
31				0.9 0.7 2.3 2.9	2.9 2.9 2.8 4.1	19.5

Greenwich day is greater than in the first half considering the whole Earth.

The utilization of K-indices for assistance in currently selecting the five international quiet and disturbed days has been continued. The selected days for 1943 and for the first quarter of 1944 have appeared in previous issues of this JOURNAL while those for the second quarter of 1944 appear in the current issue.

Referring further to the question of comparative geomagnetic activity from 1940 to date, an excellent indicator is the u-measure of activity. Bartels defined this measure for a day as the difference (without regard to sign) between the mean value of horizontal intensity in gammas on that day as compared with the preceding day. The average

TABLE 2—*Mean K-indices by months from twenty-seven observatories, 1943*

Month	Mean indices, K_M, for GMT 3-hour interval								
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24	Mean
Jan.	1.83	1.60	1.86	2.06	1.99	2.27	2.00	2.04	1.96
Feb.	1.89	1.77	1.89	2.14	1.88	1.74	2.02	1.82	1.89
Mar.	2.01	1.88	2.09	2.33	2.26	2.36	2.40	2.24	2.20
Apr.	2.33	2.25	2.44	2.44	2.34	2.16	2.07	2.14	2.27
May	2.49	2.40	2.48	2.37	2.30	2.28	2.14	2.23	2.34
June	2.22	2.35	2.36	2.51	2.34	2.15	1.98	2.12	2.25
July	2.49	2.53	2.73	2.72	2.46	2.41	2.35	2.31	2.50
Aug.	3.17	3.30	3.46	3.35	3.37	3.20	3.00	2.98	3.23
Sep.	3.19	3.24	3.06	3.29	3.10	2.99	3.00	3.02	3.11
Oct.	2.86	2.61	2.83	3.02	3.08	2.83	2.85	2.73	2.85
Nov.	2.30	2.48	2.72	2.60	2.71	2.79	2.73	2.48	2.60
Dec.	2.03	1.80	2.01	2.36	2.50	2.56	2.45	2.26	2.25
Year	2.40	2.35	2.49	2.60	2.53	2.48	2.42	2.36	2.45

TABLE 3—*Mean K-indices by years from 1940 to 1943*

Number of observatories	Year	Mean indices, K_M, for GMT 3-hour interval								
		00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24	Mean
27	1940	2.12	2.05	1.95	2.09	2.24	2.29	2.34	2.22	2.16
29	1941	2.21	2.14	2.20	2.28	2.31	2.34	2.39	2.35	2.28
28	1942	2.14	2.08	2.13	2.29	2.38	2.37	2.28	2.22	2.24
27	1943	2.40	2.35	2.49	2.60	2.53	2.48	2.42	2.36	2.45
	Mean	2.22	2.16	2.19	2.32	2.36	2.37	2.36	2.29	2.28

of these differences divided by ten for any observatory is reduced to a u-measure comparable with that from other observatories by a conversion-factor. In the case of Huancayo, the conversion-factor is 0.84. The monthly means of u for Huancayo from January, 1940, to September, 1944, are given in Table 4. Running averages by twelves show that the activity is now slightly greater than 0.70 and indicates that the low of activity for this sunspot-cycle has been, or soon will be, reached.

Table 4—*Monthly means of u for Huancayo from January, 1940, to September, 1944*

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1940	1.20	0.81	1.60	1.33	1.15	1.46	0.80	1.06	0.93	1.23	1.37	0.75	1.14
1941	0.83	0.94	2.23	0.79	0.71	0.83	2.13	1.34	2.07	1.10	1.26	0.86	1.26
1942	0.72	1.19	1.41	1.10	1.15	0.73	0.69	0.64	0.68	0.97	0.82	0.77	0.91
1943	0.72	1.06	0.97	1.11	0.75	0.79	0.43	0.88	0.87	0.57	0.84	0.88	0.82
1944	0.60	0.78	0.87	1.01	0.59	0.50	0.61	0.82	0.59	.....	.....	.....	.....

Character-figures on a scale of 0, 1, and 2 have now been received from 39 observatories. *Preliminary* international character-figures, *C*, for 1943 are given in Table 5. The average for the year is 0.68 as compared with a value of 0.64 for 1942 from 43 observatories.

Table 5—*Preliminary International Character-Figures, C, for* 1943
(Data from 39 observatories)

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	0.4	0.3	0.4	0.7	1.4	0.4	0.1	1.0	1.2	1.3	1.2	0.4
2	0.2	0.2	0.9	0.8	1.1	0.3	0.2	1.1	1.2	1.5	0.2	0.9
3	0.4	0.5	0.6	1.3	0.7	0.1	0.8	1.2	1.4	1.5	0.2	1.1
4	1.4	0.7	1.2	1.0	0.3	0.1	1.4	1.2	1.1	1.0	0.1	0.9
5	0.9	0.7	0.9	1.1	0.4	0.3	1.4	1 1	0.9	0.3	0.6	0.5
6	0.4	0.6	0.4	1.2	0.2	0.6	1.4	0.7	0.3	0.2	1.2	0.1
7	0.0	0.3	0.4	0.9	0.2	0.7	0.8	1.0	0.1	0.8	0.6	0.1
8	0.4	0.4	0.4	0.3	0.0	1.3	1.1	1.7	1.0	1.2	0.5	0.2
9	0.2	0.3	0.3	0.1	0.1	1.1	1.3	1.1	1.2	1.4	0.4	0.3
10	0.3	0.2	0.1	1.2	0.2	1.0	1.1	0.3	1.1	0.9	0.4	0.4
11	0.2	0.4	0.9	1.3	0.6	0.7	1.1	0.2	0.9	0.6	0.1	0.1
12	0.3	0.3	1.1	0.1	0.6	0.9	0.9	0.4	0.9	0.5	0.2	0.1
13	0.1	0.8	0.1	0.1	1.0	1.0	0.8	1.6	1.0	0.3	0.2	0.2
14	0.0	0.2	0.2	0.0	0.6	0.7	0.1	1.2	0.9	0.1	0.2	0.6
15	0.1	0.2	0.1	0.4	1.0	0.2	0.4	0.9	0.6	0.1	0.2	0.3
16	0.4	0.4	1.2	0.6	0.8	0.1	0.4	1.2	0.4	0.2	0.6	1.6
17	1.3	1.6	0.6	0.3	1.1	0.1	0.6	1.0	0.3	0.4	0.1	1.2
18	0.6	0.5	0.3	0.1	1.3	0.1	1.0	1.4	0.3	0.2	0.4	1.0
19	0.3	0.4	0.8	0.1	1.0	0.7	0.7	1.4	0.4	0.3	1.7	1.5
20	1.5	0.3	1.2	0.5	0.2	1.1	0.3	1.3	0.2	0.7	1.5	1.2
21	1.3	0.2	0.4	1.0	0.2	1.1	0.6	0.7	1.0	0.2	1.5	0.9
22	1.2	0.2	1.1	0.3	0.0	1.0	0.7	0.2	0.9	1.0	1.1	0.8
23	0.5	0.4	1.2	0.0	0.5	1.1	0.2	0.3	0.4	0.4	1.5	0.6
24	0.4	0.5	0.4	0.0	1.1	1.1	0.2	0.8	0.2	1.5	1.5	0.3
25	0.1	1.0	0.2	0.7	1.1	0.7	0.1	0.7	0.5	1.3	1.6	0.4
26	0.8	1.2	0.3	1.2	0.5	0.2	0.4	0.8	1.3	1.7	1.5	0.8
27	0.5	0.6	0.2	0.4	0.8	0.4	0.3	0.2	1.3	1.3	1.4	0.3
28	0.6	0.2	0.2	0.4	1.2	1.2	0.2	1.3	1.4	1.3	1.0	0.2
29	0.2		1.4	0.6	0.7	0.2	0.2	1.4	1.6	1.3	1.1	0.4
30	0.3		1.3	1.1	0.3	0.0	1.0	1.8	1.8	1.3	0.3	0.3
31	0.2		0.9		0.2		0.7	2.0		1.2		0.7
Mean	0.50	0.49	0.64	0.59	0.63	0.62	0.66	1.01	0.86	0.84	0.77	0.59

Mean for year: 0.68

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington 15, D. C., October 30, 1944

AMERICAN MAGNETIC CHARACTER-FIGURE, C_A, THREE-HOUR-RANGE INDICES, K, AND MEAN K-INDICES, K_A, FOR JULY TO SEPTEMBER, 1944, AND FIVE INTERNATIONAL QUIET AND DISTURBED DAYS FOR APRIL TO JUNE, 1944

By H. F. Johnston

Summaries of American *URSI* broadcasts have appeared regularly in this Journal since the issue for December, 1930.

As set forth in this Journal for June, 1937, "The Department of Terrestrial Magnetism and the United States Coast and Geodetic Survey with the cooperation of the United States Army and the United States Navy communication-services and several amateur radio stations have undertaken to supply the American character-figure based upon the

Table 1—*American magnetic character-figure C_A for Greenwich half- and full-days based on reports from Cheltenham, Honolulu, Huancayo, San Juan, Sitka, Tucson, and Watheroo for July to September, 1944*

Day	July			August			September		
	0^h-12^h	12^h-24^h	0^h-24^h	0^h-12^h	12^h-24^h	0^h-24^h	0^h-12^h	12^h-24^h	0^h-24^h
1	0.0	0.1	0.1	0.4	0.2	0.3	0.6	0.4	0.5
2	0.0	0.1	0.0	0.4	1.1	0.7	1.1	0.6	0.9
3	0.1	0.4	0.3	1.7	0.6	1.2	0.4	0.0	0.2
4	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.4	0.2
5	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.0	0.1
6	0.1	0.0	0.0	0.4	0.0	0.2	0.0	0.1	0.1
7	0.4	0.1	0.2	0.0	0.1	0.1	0.5	0.0	0.2
8	0.0	0.0	0.0	0.0	0.4	0.2	0.1	0.3	0.2
9	0.8	0.4	0.6	0.1	0.1	0.1	0.1	0.0	0.1
10	0.1	0.4	0.2	0.7	0.2	0.5	0.2	0.4	0.3
11	0.1	0.0	0.0	0.4	0.3	0.4	0.0	0.2	0.1
12	0.0	0.0	0.0	0.6	0.2	0.4	0.4	0.1	0.3
13	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.4	0.2
14	0.2	0.1	0.2	0.0	0.4	0.2	0.4	0.4	0.4
15	0.5	0.3	0.4	0.4	0.1	0.2	0.3	0.0	0.1
16	0.0	0.4	0.2	0.0	0.4	0.2	0.0	0.0	0.0
17	0.5	0.1	0.3	0.0	0.0	0.0	0.0	0.2	0.1
18	0.0	0.1	0.0	1.1	0.4	0.8	0.4	0.1	0.2
19	0.3	0.4	0.3	0.4	0.0	0.2	0.0	0.0	0.0
20	0.9	0.1	0.5	0.0	0.0	0.0	0.0	0.8	0.4
21	0.4	0.4	0.4	0.0	0.0	0.0	0.9	0.1	0.5
22	0.4	0.1	0.2	0.1	0.1	0.1	0.1	0.4	0.2
23	0.2	0.0	0.1	0.7	0.4	0.6	0.4	0.5	0.5
24	0.0	0.0	0.0	0.7	0.5	0.6	0.9	0.5	0.7
25	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.3
26	0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.3
27	0.0	0.1	0.0	0.3	0.2	0.2	0.4	0.5	0.5
28	0.0	0.2	0.1	0.9	0.6	0.8	0.2	0.0	0.1
29	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0
30	0.1	0.1	0.1	0.4	0.3	0.3	0.0	1.2	0.6
31	0.4	0.1	0.2	0.9	0.4	0.6			
Means	0.2	0.1	0.2	0.3	0.2	0.3	0.3	0.3	0.3

Table 2--Three-hour-range indices, K, July to September 1944

July 1944

	1	2	3	4	5	6	7	8
Si	2211 1222	2223 2211	1124 2221	2200 0131	2121 1111	1221 1121	3323 2222	2212 2121
Ch	3111 2232	2312 2122	1212 2223	3200 0032	3221 2222	2211 0123	4321 1222	1222 1122
Tu	3211 2222	2322 2222	1123 3323	3210 0032	3121 2222	1222 1122	4422 2222	1212 2222
SJ	3011 2232	2201 0012	1122 1123	3200 1221	2201 1100	1211 0011	3210 1011	0111 1112
Ho	0101 1110	1212 1112	0123 2222	2100 0021	1011 1111	1111 0003	3313 2111	1002 0111
Hu	3110 3211	2201 2222	1111 2322	2200 0131	2100 2210	1211 1111	3211 2221	0211 1121
Wa	1111 2211	1212 2121	1122 2222	2211 1110	2111 1321	1111 1222	2211 1211	1111 1111
	9	10	11	12	13	14	15	16
Si	1454 3321	2311 1222	2330 2221	1201 0122	3222 2222	1123 1222	2344 4222	2222 3212
Ch	4343 2233	3301 2232	3311 0112	2211 1122	2231 1133	1123 1223	3342 2123	1221 2233
Tu	2443 2222	3312 2233	2321 0112	2212 1112	2231 1222	2123 2234	2342 2232	1231 2222
SJ	3233 1122	3100 1121	2310 0011	1201 0311	1121 1111	1122 0121	2232 1022	0120 1221
Ho	1233 1122	2001 1111	0011 0011	1102 1000	1121 1111	1013 0121	2221 1111	0120 2211
Hu	2232 2321	2100 3321	2311 2111	1101 2210	1120 2221	1012 2321	2231 3221	0121 3321
Wa	2333 2322	2111 1231	1211 2111	2211 1311	2121 1111	1123 1121	1123 3122	1222 3233
	17	18	19	20	21	22	23	24
Si	2443 2222	2221 1122	2212 3112	2336 3112	2244 4233	1242 1222	1132 1211	1110 1011
Ch	1432 2231	2201 0033	2222 3222	3334 2112	2333 2233	2233 1222	2133 0211	0020 0012
Tu	2432 1222	2211 1134	4232 3223	2245 2112	1333 3222	2342 2233	2133 1111	1020 1012
SJ	0221 0211	2200 0122	1222 2212	3323 2101	1222 0211	1230 2111	1021 0100	0010 1001
Ho	1221 1111	0100 0010	2222 3112	2135 2111	1122 2211	1132 1121	1022 0000	0010 0001
Hu	1211 2221	1100 1222	2112 3322	3233 3212	1212 2321	1221 2221	1010 2210	0010 1100
Wa	1332 2232	1111 1131	2123 3211	1234 3111	1223 3232	1222 1331	1122 1211	1111 0111
	25	26	27	28	29	30	31	
Si	2010 1111	1101 1100	0010 1111	1000 1112	2112 1212	1122 1112	2221 2111	
Ch	1200 1101	1211 0011	0010 1121	1000 1223	2101 1123	2222 2112	3222 1123	
Tu	1200 1001	1212 0121	1020 1221	0001 0023	2212 1213	2222 2212	2322 2123	
SJ	0101 1000	1112 0000	0001 0221	0000 0122	2101 1111	1111 1102	2222 1111	
Ho	1000 0100	0112 1011	0010 1212	1001 0022	1102 1112	1011 0102	1122 1001	
Hu	0000 1110	0112 2200	0000 2320	0000 2221	2101 2220	1110 2201	2112 3211	
Wa	1121 1111	2222 2111	0111 2211	1101 1212	1112 2122	1222 1112	1323 2222	

August 1944

	1	2	3	4	5	6	7	8
Si	2344 4211	1222 2223	7776 5223	2132 2121	1102 1123	2243 1122	2111 1211	1103 1322
Ch	3232 3222	2322 3335	7766 2133	4111 1221	2101 1223	3233 2222	3211 2122	2112 1232
Tu	2333 2122	3323 3445	6666 3223	3121 2312	2202 2233	3333 2221	3211 1212	1223 2322
SJ	2222 1010	2322 3334	5544 2122	3001 1111	0101 1112	2221 1110	0101 0011	1112 1232
Ho	0222 1100	2202 3234	6455 3111	1010 2010	1102 1112	2221 1111	1101 1111	0111 1212
Hu	2221 2120	1223 4542	4442 3222	2102 2221	0100 2212	2211 2321	2101 2211	1111 2321
Wa	1213 4111	2222 3333	5555 5232	2111 3211	1112 1223	2232 1211	1111 3211	1111 1422
	9	10	11	12	13	14	15	16
Si	2311 1111	2254 2322	3331 1123	4422 2211	2132 1111	1100 1121	2213 2122	1123 2212
Ch	3321 1222	2243 2222	4321 1134	4332 2222	3132 1122	1101 2232	2322 1012	1211 1223
Tu	3311 1232	3344 3222	4321 2123	5422 2223	3132 1121	1101 2233	2322 2222	2111 2223
SJ	2211 1221	2232 1111	3320 1113	4422 1111	3020 0010	1101 1121	2321 0011	1101 2112
Ho	2110 0211	1223 1111	2110 1112	3222 1101	2011 0010	0001 1221	1222 1101	1101 1112
Hu	2211 2321	2232 3331	3220 2222	4311 3321	3020 2220	1001 3332	2221 2221	1101 3222
Wa	2211 1321	2333 3331	3221 2222	4332 2111	2111 1121	1011 1132	2223 2121	1112 2212
	17	18	19	20	21	22	23	24
Si	2220 0111	2276 3222	2343 2211	1222 3110	1102 1221	1324 3112	2233 5222	1454 5321
Ch	3211 0022	4264 3132	3331 0113	2211 1122	3101 0111	1213 1113	4343 2133	3344 3312
Tu	3221 0112	3264 2232	3432 1113	2221 2111	2112 1111	1313 1113	3342 4122	3343 3322
SJ	3211 0012	3243 2121	2311 0011	1110 0011	2000 0011	1203 0002	3222 1002	2232 2211
Ho	0100 0012	2144 2111	2230 0001	2000 1100	0001 0000	0001 0000	2222 3111	1233 3111
Hu	3110 2211	2243 3232	2211 1111	2111 2110	2000 1110	1201 1211	2322 2221	2222 4421
Wa	1111 1011	1255 3332	2332 2211	1112 2111	1111 1121	1112 3112	2323 3322	1234 3421
	25	26	27	28	29	30	31	
Si	0111 1211	1000 1221	2240 1122	2354 4322	1001 1111	1332 3222	2454 2321	
Ch	0301 0111	1100 1123	2220 1143	2353 3333	1001 2122	3422 1233	3343 1322	
Tu	0201 1211	0111 1222	3330 0132	2453 4323	1101 1122	2332 2223	3453 1323	
SJ	0100 0010	0000 0112	2110 0032	1253 3212	1000 1111	2322 0111	2333 0312	
Ho	0000 0000	0000 0121	1210 1021	1344 2221	1001 0100	1321 2101	2233 0201	
Hu	0100 1210	0000 2221	2110 2231	1242 4432	1001 2221	2221 2331	2332 2421	
Wa	1101 1211	1111 0222	2321 1132	2345 4333	1111 1211	2322 3132	3333 2432	

.. Interpolated

Table 2--Three-hour-range indices, K, July to September 1944--concluded

September 1944

	1	2	3	4	5	6	7	8
Si	4223 3222	3555 5332	2143 1112	2101 1222	2222 3100	1112 1222	1233 1110	0134 3322
Ch	5222 3112	5554 2333	3142 1121	2201 1133	3221 0111	1102 1222	2322 1111	1122 2123
Tu	4322 3113	4554 3233	4142 2211	2201 1122	4222 2101	1103 1132	2333 2111	1132 2233
SJ	4221 1103	3443 1222	2031 0000	1100 0012	1201 0001	1102 0122	1322 0100	0122 1011
Ho	3121 2122	3444 2211	2121 0000	1101 0122	2101 1101	0002 0222	1233 0000	1012 2011
Hu	4211 3221	3332 2322	2011 2311	1102 2332	1201 2200	1003 2321	1221 2210	0111 2220
Wa	3223 3211	3444 3333	2233 2111	2111 1132	3222 2112	1112 1122	2323 1111	1112 2232
	9	10	11	12	13	14	15	16
Si	1211 1021	2133 1222	2132 1112	2344 4211	1002 1222	1321 2221	1323 0001	1121 1211
Ch	3201 1122	2232 1233	2222 1123	3333 2112	2001 2234	4421 2222	2322 1011	1221 1112
Tu	2211 1112	1232 2223	2232 2223	3334 3122	2002 2244	3322 2322	2322 1001	1220 1212
SJ	1100 0011	2121 1112	2110 0022	2112 1001	1002 0222	3312 1111	2311 1001	1110 0101
Ho	1101 0011	1131 0122	1111 1022	1123 3000	0001 0122	1211 1101	1111 0001	1120 1200
Hu	1102 2221	2210 2322	2112 3322	2211 3211	1001 2332	3312 3422	2210 1111	0110 2211
Wa	1322 1121	1122 2333	2121 2212	2123 3121	1011 1322	2222 3221	2212 2101	1211 1211
	17	18	19	20	21	22	23	24
Si	1102 1112	3442 3221	1022 1110	0022 3223	4343 3122	2211 1122	2233 1123	5366 5322
Ch	1112 2112	3331 1121	0011 1120	0011 1135	6433 2123	3211 2224	3332 1234	5355 3133
Tu	1112 2222	4332 2110	0111 1011	0121 2245	5433 2122	2201 2324	3332 1244	5455 3333
SJ	1102 1211	3320 0000	0000 0110	0000 1335	4223 2112	2101 1223	3320 1235	3344 3222
Ho	0001 1211	2221 2000	1101 0100	0111 2234	4333 0011	2101 2111	1121 0234	4244 2123
Hu	1001 2320	3220 2220	0011 3110	0100 2344	4122 2321	1101 3322	2321 2322	2222 4233
Wa	1111 1212	2321 2121	1111 1011	1212 3234	5233 2232	2222 2223	3332 1223	4444 4223
	25	26	27	28	29	30		
Si	2423 2222	3233 3311	1453 3322	1232 1211	1223 1121	0122 6643		
Ch	3421 2133	4232 1123	1442 2333	2322 1121	2323 1211	1122 4555		
Tu	3422 2132	4242 2213	1442 2333	2333 2111	0332 2222	2122 4565		
SJ	3311 0132	3121 1112	0321 0323	1220 0120	1231 2112	1021 2253		
Ho	2222 2020	3132 2112	0232 1221	0122 1011	1122 2100	1112 3344		
Hu	2211 3231	2112 3321	0222 2332	1121 2220	1221 3221	1121 4453		
Wa	2333 3221	3332 4312	2233 2342	1222 2221	1221 1121	1212 5534		

Table 3--Weighted average of reduced three-hour-range indices, July to September 1944

Day	July 1944									August 1944									September 1944								
	Values K_A								Sum	Values K_A								Sum	Values K_A								Sum
1	2	1	1	1	2	2	2	1x	12x	2	2	2	2x	2x	1x	1x	1	15	4	2	2	2	3	1x	1	2	17x
2	1x	2	1	2	1x	1x	1x	1x	12x	2	2	2	2x	3	3	3	3x	21	3x	4x	4	4	2x	3	2x	2x	26x
3	1	1	1x	2x	2	2	2	2	14	6	5x	5	5	3x	1x	2x	2x	31x	2x	1	3	2	1	1	1	1	12x
4	2x	1x	0x	0x	0x	0x	2x	1	9x	2x	1	1	1x	2	1x	1x	1	12	2	1x	0	1	1	1x	2x	2	11x
5	2	1	1x	1	1x	2	1x	1	11x	1	1	0	1x	1	1x	2	2x	10x	2x	2	1x	1x	1x	1	0x	1	11x
6	1x	1x	1x	1x	0x	1	1x	2	11	2x	2	2x	2x	1x	1x	1x	1	15	1	1	0x	2	1	2	2	2	11x
7	3	2x	1x	1x	1x	1x	1x	1x	14x	2	1	0x	1	1x	1x	1	1	9x	1x	2x	2x	2x	1	1	0x	0x	12
8	1	1x	1	2	1	1	1x	1x	10x	1	1	1	2	1	3	2	2	13	0x	1	2	2	2	1x	2	2	13
9	2x	2x	3x	3	2	2x	2	2	20	2x	2	1x	1	1	2	2	1	13	1x	2	0x	1x	1	0x	1x	1x	10
10	2x	1x	0x	1	1x	2	2x	1x	13	2	2	3x	3	2	2x	2	1x	18x	1x	1x	2x	1x	1x	2	2	2x	15
11	2	2	1x	1	1	1	1	1	10x	3	2x	2	1	1x	1x	2	2x	16	2	1x	2	1x	1x	1x	1x	2x	14
12	1x	1x	0x	1x	1	1x	1	1	9x	4	3	2	2	2	1x	1x	1x	17x	2x	2	2x	3	3	1	1	1	16
13	2	1x	2	1	1	1x	2	1x	12x	2x	0x	2	1x	1	1	1x	1	11	1	0	0	1x	1x	2x	2x	2x	11x
14	1x	1	2	3	1	1x	2	1x	13x	1	0x	0	1	1x	1x	2x	1x	9x	2x	3	2	1x	2x	2x	1x	1x	17
15	2	2	3	2x	2x	1x	2	2	17x	2	2	2	2	1x	1	1x	1x	13x	2	2x	1x	1x	1	0	0	1	9x
16	1	1x	2	1x	2	2	2	2	14	1x	1	1	1x	2	2	1x	2	12x	1	1x	1x	0x	1	2	0x	1	9
17	1x	3	2x	2	1x	2	2	1x	16	2	1x	1	0x	0x	0x	1	1x	8x	1	1	0x	1x	1x	2	1	1x	10
18	1x	1x	0x	1	0x	0x	2x	2	10	2x	1x	5	4	2x	2	2x	1x	21x	3	3	2x	1	1x	1	1x	0x	14
19	2	1x	2	2x	3	2	1x	2	16x	2x	2x	2x	1x	1	1	1	1x	13x	0x	0x	1	1	1	1	1	0x	6x
20	2	2	3	4	2x	1	1	1x	17	1x	1	1	1x	1x	1	1	0x	9	0	1	1	1	2	2	3	4x	14x
21	1x	2	2x	3	2x	2	2x	2	18	1x	0x	0x	1	0x	1	1	1	7	5	2x	3	3	2	1x	2	2	21
22	1x	2	3	2	1x	2	2	1x	15x	1	1x	1	2x	1x	1	0x	2	11	2	2	1	1x	2	2	1x	3	15
23	1x	0x	2	2	1	1x	0x	0x	9x	2x	2x	2x	2x	3	1x	2	2	18x	2x	2x	3	1x	1	2	2x	3x	18x
24	0x	0x	1x	0x	0x	0	0x	1	5	2	2x	3x	3x	3	3	1x	1	20	4	3	4	4x	3x	2	2x	3	26x
25	1	1	0x	0x	1	1	0x	0x	6	0x	1x	0	1	0x	1x	1	0x	6x	2x	3	2	2	2	1x	2x	1x	17
26	1	1x	1	2	1	0x	0x	0x	8	0x	0x	0x	0x	0x	1x	2	1x	7x	3x	2	3	2	2x	2	1	2	18
27	0	0	1	0x	1	1x	1x	1	6x	2	2	2	0x	1	1	3	2	13x	1	3	3	2	2	3	2x	2x	19
28	1	0	0	0x	1	1	1x	2	7	1x	2x	4x	3x	3x	3	2x	2x	23x	1	2	2x	2	1x	1x	1x	1	13
29	1x	1	0x	2	1x	1x	1x	2	11x	1	0x	0	1	1	1x	1x	1	7x	1x	2x	2x	2	1x	1x	1x	1	14
30	1x	1x	1x	1x	1x	1	0x	2	11	2	3	2	2	2	1x	2	2	16x	1	1x	2	2	4	4x	4x	4	23x
31	2	2	2	2	1x	1	1x	1x	13x	2x	3	3x	3	1	3x	2	1x	20									

reports of the seven American-operated observatories—those of the Department of Terrestrial Magnetism at Huancayo in Peru and at Watheroo in Western Australia, and those of the United States Coast and Geodetic Survey at Cheltenham (Maryland), Honolulu (Hawaii), San Juan (Puerto Rico), Sitka (Alaska), and Tucson (Arizona)." This character-figure is being designated C_A, and its values for the first twelve, the second twelve, and all twenty-four hours of each Greenwich day for July to September, 1944, are given in Table 1.

The three-hour-range indices, K, have been compiled since April 6, 1940, for each of the seven American-operated observatories. The eight indices for each day give geomagnetic activity for three-hour periods successively during the Greenwich day. The indices range from "zero" very quiet to "nine" extremely disturbed. The K-indices for Sitka (Si), Cheltenham (Ch), Tucson (Tu), San Juan (SJ), Honolulu (Ho), Huancayo (Hu), and Watheroo (Wa), for July to September, 1944, are given in Table 2. Interpolated indices are shown thus, $\ddot{3}$.

In the manner set forth in the Journal for September, 1940, the indices are standardized into reduced indices K_r to eliminate local variations. A weighted mean index K_A, is derived from the reduced indices. The reduced indices from Si, Ch, and Wa are given double weight and those from Tu, SJ, Ho, and Hu are given single weight. The weighted indices, K_A, for July to September, 1944, are given in Table 3. A superior cross ($^{\times}$) following an index-number denotes a half-unit, thus $5^{\times}=5.5$, etc.

Reports of geomagnetic activity for the second quarter of 1944 have been received from a sufficient number of magnetic observatories so that the international quiet and disturbed days may be selected in accordance with the method outlined on pages 219-227 in the December 1943 issue of this Journal. The selection is based on the reports of magnetic character on a scale of 0, 1, and 2 from 30 observatories and of K-indices from 20 observatories.

Month, 1944	Quiet					Disturbed				
April	13	14	19	22	23	2	4	5	6	16
May	13	16	18	20	21	1	2	4	6	29
June	3	7	8	10	12	15	21	22	23	26

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington 15, D. C., October 30, 1944

NOTES

(See also page 281)

33. *Magnetic observations in the Nordenskiöld Archipelago, 1938-1939*—In volume 180 of the *Transactions of the Arctic Institute* are given the results of the magnetic observations made at the temporary station of Jekman Island of the Nordenskiöld Archipelago. The approximate geographic position of the station is latitude 76° 25′.7 north and longitude 95° 08′.2 east. The magnetic results cover the period December, 1938, to June, 1939, and contain the diurnal variation as departures from the monthly means in declination and horizontal intensity for (1) all days, (2) calm days, and (3) disturbed days. Observations in declination had been made on Jekman Island for a brief period in 1936-37. In preparing for the winter expedition to the Archipelago in 1938, it was decided to repeat the observations on a larger scale and over a longer period. A variation hut was built of wood on the shore of a deep bay on the island and the absolute observations were also made in a wooden hut which was later replaced by one made of snow like an Eskimo igloo. This was found to be more suitable since it afforded a sure protection from the wind and was much warmer. In all 24 absolute observations were made averaging three per month.

34. *Notes on the compass*—The following extract from "Physics and the scientific instrument industry" by A. J. Philpot [Proc. Phys. Soc., **56**, No. 316, 267-268 (1944)] is of interest to readers of the JOURNAL.

The compass is an ancient instrument operating according to laws known to antiquity. A large number of modern compasses are not of the "dry" type, but are instruments in which the magnet with its attached compass-card moves in a liquid contained in a liquid-tight compass bowl. The liquid is chosen of such viscosity as will allow the rate of motion of the magnetic system to be most suited to the particular conditions of use. In the compass is a variety of metals of which the bowl itself, the pivot, the pivot-holder, the solder, and other parts are composed. All of these are immersed in a liquid, and should such a compass be constructed in the absence of any knowledge of contact-differences of potential and of the laws of electrolytic action, disaster may well ensue. The compass, instead of serving as a safeguard and a help of the mariner or airman, may well be used as a showcase for the demonstration of the physics of corrosion. An instance was brought to the notice of the British Scientific Instrument Research Association a few years ago of a certain type of liquid compass suddenly developing marked corrosion after a long history of satisfactory use. It was shown that the occurrence of this defect was solely due to the employment of a minute joint of solder which differed slightly in composition from that previously employed in the trouble-free compasses. An innocuous potential system had thus been converted into a vicious one. The craftsman's skill and the knowledge that one pole of a magnet tends to point to the north are not sufficient for the manufacture of a sound liquid compass. A much wider knowledge of physics must be behind the manufacture if the many pitfalls are to be avoided.

35. *Frank B. Jewett fellowships in physical sciences*—The American Telephone and Telegraph Company has inaugurated a series of post-doctorate fellowships, intended to stimulate and to assist research in the fundamental physical sciences, and particularly to provide their holders with opportunities for individual growth and development as creative scientists. A trust fund sufficient to finance five of these fellowships in each of the ten years, 1945-54, has been established. Five members of the staff of the Bell Telephone Laboratories, Inc., will serve as trustees and award the fellowships. Each fellowship is for the term of one year, starting July 1, but may be extended by renewal to cover the succeeding year, but no individual may receive awards for more than two terms. Each fellowship carries an honorarium of $3,000, and an honorarium of $1,500 will be paid the academic institution towards defraying the expense of the facilities provided. In the selection for fellowship awards the primary criteria will be: Demonstrated research ability of the applicant; the fundamental importance of the problem he proposes to attack; and the likelihood of his growth as a scientist. Applications for fellowships should be addressed to the Frank B. Jewett Fellowship Committee, Bell Telephone Laboratories, Inc., New York 14, New York. Each application, which should be received prior to December 1 preceding the term of the fellowship, should contain biographical and scholastic data, description of the research problem on which the applicant is at the time engaged, or has recently completed, and an analysis of the problem in which he would expect to engage, if appointed.

36. *Direction-indicator*—A new direct reading magnetic direction-indicator compass, Type 2221, has been announced by Autoflight Corporation of Burbank, California. The instrument is particularly adapted to passenger, cargo, and private aircraft. The azimuth-pointer rotates in front of a fixed vertical dial, making the compass exceptionally easy to read, and the settable course-reference lines further relieve pilot strain over long flights. This instrument uses a standard 3.25-inch luminous dial, graduated every 2°, and combines a short period of swing with a low value of overswing and a high lateral dynamic stability—these result in quick response and high stability in rough air. The entire mechanism is permanently immersed in fluid, which insures a complet- absence of friction. Wide-range temperature and magnetic compensae tion are provided within the housing. The total weight is 1.1 pound.

37. *Geiger tube*—Workers in radiation now have commercially available a practical, well-constructed Geiger tube, manufactured by the Cyclotron Specialties Company, Moraga, California. This new Geiger-counter tube, 3.5 inches in diameter by 5 inches long, has a mica window, only 0.0006 inch thick with an effective area of 15 square centimeters. It has an exceptionally level broad plateau of 250 volts, with a background of only one or two counts per second when shielded with two inches of lead. The sensitivity to beta-rays is high, and the over-all efficiency is at least 40 per cent.

LIST OF GEOMAGNETIC OBSERVATORIES AND THESAURUS OF VALUES†—VII

By J. A. Fleming and W. E. Scott

Table 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, +=N −=S	Longitude, east	Year	Declination, D	Inclination, I	Components of intensity: Horizontal, H	North, X	East, Y	Vertical, Z	Total, F
*Corrections and additional results received since publication of Parts I to VI***										
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Teplitz Bay[1] Camp Abruzzi	+81 48	57 59	1904[m]	+22 42.0	+83 12.4	6766	6242	+2611	+56798	57200
Baie Tichaja[2] (Calm Bay)	+80 20	52 48	1937	+22 08.2	**	**	**	+2439	**	**
			1940	+22 54.0	+83 20.5	6388	5885	+2486	+54721	55093
			1941	+23 07.7	+83 22.4	6355	5844	+2496	+54699	55067
Refuge Harbor[2] (Greenland)	+78 32	287 37	1924[n]	−99 49.5	+85 47.1	4136	706	−4075	+56118	56270
Chelyuskin[2]	+77 43	104 17	1936	**	+86 02.8	3979	3596	+1703	**	57722
			1940	+24 57.5	+86 12.0	3850	3490	+1625	+57972	58100
Jekman Island	+76 26[o]	95 08[o]	1939[p]	+29 14.2[2]	+85 11.6[1]	4799[2]	4188	+2344	+57070[q]	57271[q]
Dickson[2]	+73 30	80 25[r]	1940	**	+83 22.1	**	**	**	+57174	57559
Matochkin Shar[2]	+73 16	56 24	1940	+22 41.1	+80 40.9	8902	8213	+3433	+54251	54977
King Point[2]	+69 07	221 52	1906[s]	+42 25	+81 51.6	8448	6237	+5698	+59061	59662
Gjöahavn[2]	+68 37	264 07	1903[t]	− 8 54	+89 18.1	738	729	− 114	+60488	60493
			1904	− 7 24	+89 16.7	761	755	− 98	+60463	60468
			1905[u]	− 6 06	+89 17.3	750	746	− 80	+60434	60439
Wellen[2]	+66 10	190 10	1938	**	+75 38.7	13694	13178	+3725	**	55231
			1939	**	+75 37.2	**	**	**	+53460	55189
			1940	+15 38.4	+75 36.2	13714	13206	+3697	+53424	55156
Yakutsk[2,v]	+62 01	129 43	1943	−17 25.2	.....	14526	13860	−4349	.....	.....
Lerwick[2]	+60 08	358 49	1930	**	**	14527	**	**	+46624	**
			1936	**	**	**	**	−3237	**	**
			1937	**	**	**	**	−3186	**	48981
			1943	−11 47.7	+72 57.7	14379	14076	−2940	+46919	49073
Slutsk[2]	+59 41	30 29	1941[w]	+ 5 16.8	+72 18.2	15228	15163	+1401	+47725	50096
Vyssokaya Dubrava[2]	+56 44	61 04	1943	+13 01.3	+72 38.4	16041	15629	+3614	+51312	53761

†Continued from Terr. Mag., **48**, 97-108 (which see for numbered footnotes), 171-182, and 237-242 (1943), **49**, 47-52, 109-118, and 199-205 (1944).

**Corrected values are indicated only for the particular element concerned; double asterisks (**) in column indicate values as previously published are correct. It is to be noted that in general no corrections in values of X, Y, F, and Z or I—computed values utilizing D, H, and I or Z—are indicated unless the correction in value published in the preceding Parts I to VI of this List is greater than one gamma.

[m]October 4, 1903, to July 1, 1904; small corrections have been made to the intensity-values published in "The Ziegler Polar Expedition, 1903-1905: Scientific results." [n]October, 1923, to June, 1924. [o]Position supplied by U. S. Hydrographic Office. [p]December, 1938, to June, 1939. [q]It was not possible to set up a Z-variometer for normal registration; absolute observations of I were made, usually once every five days, and Z was computed from mean value of H by magnetograph using mean value of I. [r]The value for longitude, as corrected by Dr. N. Pushkov, is 80° 25′ east instead of 80° 24′ as published in Part I (Terr. Mag., **48**, p. 99). [s]October 18, 1905, to March 31, 1906; *Gjöa* Expedition of Captain R. Amundsen. [t]November and December, 1903. [u]January to May, 1905. [v]Dr. N. Pushkov advises preferred spelling is Yakutsk and not Jakutsk as published previously in Part V (Terr. Mag., **49**, p. 115). [w]January to June and August, 1941.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, +=N −=S	Longitude, east	Year	Declination, D	Inclination, I	Components of intensity: Horizontal, H	North, X	East, Y	Vertical, Z	Total, F
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
Zaimishche[2]	+55 50	48 51	1943	+ 9 34.2	+71 17.3	16590	16359	+2758	+48982	51715
Eskdalemuir[2,x]	+55 19	356 48	1911	**	**	**	16003	−5264	**	**
			1912	**	**	**	16015	**	**	**
			1913	**	**	**	**	−5174	**	**
			1914	**	**	**	16003	**	**	48211
			1915	**	**	**	16001	**	45172	**
			1917	−17 17.1	**	**	**	**	**	**
			1920	−16 48.7	**	**	**	**	**	**
			1932	**	**	**	16050	**	**	**
			1937	**	**	**	16054	**	**	**
			1943	−12 31.2	+69 52.6	16516	16124	−3580	+45078	48008
Zuy[2]	+52 28	104 02	1943	− 0 42.5	+71 31.5	19023	19022	− 235	+56936	60030
Greenwich[3,y]	+51 28	0 00	**	**	**	**	**	**	**	**
Abinger[2] (Succeeding Greenwich)	+51 11	359 37	1942	−10 24.8	+66 43.9	18554	18248	−3354[z]	+43146	46966
			1943	−10 16.2	+66 44.5	18556	18259	−3308[z]	+43172	46991
Mai-Tun[2] (Succeeding Vladivostok)	+43 15	132 20	1941[a]	− 8 41.3	+58 57.1	26844	26536	−4055	+44591	52048
Dusheti	+42 05	44 42	1942	+ 4 59.6	+59 27.2	24153	24061	+2102	+40927	47522
Keles[2]	+41 25	69 12	1938	**	+60 15.1	**	**	**	+44394	51132
Capodimonte[1]	+40 52	14 15	1913	....	+56 10.3	**	.....	......	+35999	43335
			1914	....	+56 11.6	**	.....	......	+36090	43434
			1915	....	+56 12.9	.....	.....	......	....	.....
			1916	....	+56 12.8	.....	.....	......	....	.....
			1917	....	+56 15.3	.....	.....	......	....	.....
			1918	....	+56 14.9	.....	.....	......	....	.....
			1919	....	+56 17.5	.....	.....	......	....	.....
			1920	....	+56 24.9	.....	.....	......	....	.....
			1921	....	+56 11.8	.....	.....	......	....	.....
Tortosa[2] Ebro	+40 49	0 31	1936[b]	− 9 26.0	+57 21.5	23481	23163	−3849	+36657	43533
San Fernando	+36 28	353 48	1943	−10 55.7	+52 54.3	25468	25006	−4828	+33681	42226
Tucson[4]	+32 15	249 10	1935	+13 51.8	+59 40.0	26266	25500	+6293	+44890	52009
			1936	+13 51.2	+59 40.5	26237	25474	+6282	+44855	51964
Helwan[2,c]	+29 52	31 20	1937	+ 0 17.3	+42 02.8	30327	30326	+ 153	+27352	40839
Honolulu[4]	+21 19	201 56	1935	+10 09.7	+39 09.4	28542	28094	+5036	+23242	36808
			1936	+10 12.0	+39 07.5	28531	28080	+5052	+23207	36777
Teoloyucan[2]	+19 45	260 49	1940	+ 9 41.8	+47 09.3	30825	30385	+5192	+33235	45329
			1941[d]	+ 9 41.3	+47 10.7	30779	30340	+5180	+33214	45283
			1942[e]	+ 9 41.9	+47 10.6	30727	30288	+5176	+33155	45204
			1943[f]	+ 9 39.8	+47 08.5	30733	30297	+5159	+33120	45182

[x]Dr. L. A. Harwood, Meteorological Office, Edinburgh, in letter of August 17, 1944, supplied the following remarks and corrections for Eskdalemuir Observatory: "The values of D previous to 1911 are not sufficiently accurate to give reliable rates of change. Owing to arithmetical error the mean D for 1917 published in the British Meteorological and Magnetic Year Book, 1917, Part IV, p. 62, was given as $-17° 16'.3$ instead of the correct value $-17° 17.'1$. There is reason to believe that the D in 1920 was affected by structural work in the underground chamber containing the variometers. Chree suggested that the 'westerly D at Eskdalemuir in 1920 was about 1′ too high' [Mon. Not. R. Astron. Soc., Geophys. Supp., March, 1928]. This suggestion has been accepted, the annual mean D for 1920 being corrected to $-16° 48'.7$." From 1911 until 1932 at Eskdalemuir the variometers recorded the X- and Y-components directly; subsequently they recorded H and D, the values of X and Y being computed from those of H and D. [y]Dr. H. Spencer Jones in his letter of August 22, 1944, calls attention to clarification of footnote [z] in Part II (Terr. Mag., **48**, p. 173), namely: For "In 1861 the Kew new" read "In 1861 the new Kew"; the last two lines of the footnote beginning "in 1914 the dip-circle" should be changed to read "in 1914 the dip-circle was replaced by an earth-inductor and thereafter values of I were derived from continuous records of Z and H (base-line of Z-records was determined from absolute observations of I in combination with simultaneous records of X), instead of, as previously, Z from annual mean H and absolute observations of I, and annual mean H was derived throughout all the years from mean D and mean X. [z]It is to be noted that at Abinger annual mean X is derived from mean D and mean H. [a]The values are for the complete year 1941 and take the place of those given for the first three months in Part V (Terr. Mag., **49**, p. 116). [b]April to September, 1936. [c]Values published in Part IV (Terr. Mag., **49**, p. 47) were based on absolute values. [d]January to May, July, October, and November, 1941. [e]February to June and September to December, 1942. [f]January, February, April to September, and December, 1943.

TABLE 1—*Annual values of geomagnetic elements at observatories*—Continued

Observatory	Latitude, +=N −=S	Longitude, east	Year	Declination, D	Inclination, I	Components of intensity: Horizontal, H	North, X	East, Y	Vertical, Z	Total, F
	° ′	° ′		° ′	° ′	γ	γ	γ	γ	γ
San Juan [3,4] (Succeeding Vieques)	+18 23	293 53	1926[g]	**	**	**	**	**	**	**
Antipolo	+14 36	121 10	1939[3,h]	+ 0 37.4	....	.....	.....	......	....	.....
			1940[1,h]	+ 0 38.9	....	.....	.....	......	....	.....
Vassouras[2]	−22 24	316 21	1942	−13 58.8	−18 57.8	23683	22982	−5721	−8138	25042
Watheroo[2]	−30 19	115 52	1943[i]	− 3 04.4	−64 25.4	24718	24682	−1325	−51643	57254
Hermanus[2]	−34 25	19 14	1943	−23 47.1	−64 06.4	14109	12911	−5690	−29065	32309
Toolangi[1]	−37 32	145 28	1940[j]	+ 8 54.5	−67 49.5	22919	22643	+3549	−56229	60721
			1941[k]	+ 8 56.6	−67 53.1	22886	22608	+3558	−56319	60791
			1942[l]	+ 8 57.3	−67 50.7	22897	22618	+3564	−56234	60717
			1943[m]	+ 9 02.2	−67 51.1	22896	22612	+3596	−56249	60730
			1944[n]	+ 9 07.4	−67 51.0	22884	22594	+3628	−56215	60694
Amberley[2]	−43 10	172 44	1943	+18 48.4	−68 04.4	22222	21036	+7164	−55203	59508

[g]According to advice received from the U. S. Coast and Geodetic Survey the difference (San Juan—Vieques) is somewhat uncertain but the following values have been adopted: For *D*, +7′.9; for *H*, +326γ; for *I*, +18′; derived for *Z*, 797γ. It is further noted that for *D* the difference is uncertain because of faulty azimuth of mark and that difference for *I* shows large variations in individual determinations, for example, +20′, +25′, +11′, and +13′, but +18′ was adopted. [h]Values for 1939 and 1940 are from letter of August 15, 1941, from G. D. Cowie; that for 1939 depends on records of magnetographs for five international quiet days and that for 1940 depends on 24 absolute observations. [i]Finally adopted values. [j]Fifteen absolute observations during January to November, 1940; the observing hut was wrecked by a motor truck on December 13, 1940. [k]Ten absolute observations April to December, 1941, for *D* and *H* and eight observations during May to December, 1941, for *I*. [l]Thirteen absolute observations during January to December, 1942. [m]Twelve absolute observations during January to December, 1943. [n]Four observations during January, March, and April, 1944.

(*To be continued in March, 1945, number*)

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON,
Washington 15, D. C., November 11, 1944

REVIEWS AND ABSTRACTS

(See also pages 254 and 275)

A. J. OL: *Solar activity and geomagnetic perturbations.* Moscou, Bull. Acad. sci., Sér. Géog. Géophys., No. 6, 359-374 (1943). [Russian text with English summary.]

Until recently the relation between the disturbances of the magnetic field of the Earth and solar activity was established for mean characteristics only. When individual phenomena were compared on the Sun and in the magnetic field of the Earth the results were conflicting. While some investigators stated the existence of a definite relation, others refuted it. This discrepancy cannot be done away with unless viewed in the light of the impulse nature of solar activity. In comparing magnetic perturbations with the active region of the Sun, the phase of the impulse evolving in the active region needs to be taken into consideration. Geomagnetically active is mainly a distant positive phase of a geoactive impulse, and less so its zero-phase. This conclusion can be of importance for forecasting magnetic perturbations. And it also indicates the direction for further work in this field. On the other hand, the successful solution of the above discrepancies between the mean and individual characteristics of the relation of geomagnetic and solar activity points to the importance of the impulse conception of solar activity for the understanding of many problems of helio-geophysics. There is no doubt that this conception, along with the method of mappings based upon it, will later find a fruitful application to other helio-geophysical problems, as is not the case with connections between the activity of the Sun and certain phenomena taking place in the troposphere of the Earth, which have been investigated by Rubashev.

AUTHOR

Olof E. H. Rydbeck: *On the propagation of radio waves.* Göteborg, Chalmers Tekniska Högskolas Handlinger, No. 34, 168 pp. (1944).

The transmission of radio waves in inhomogeneous media is a problem of considerable theoretical and practical interest. An important contribution to the subject was made in 1930 by P. S. Epstein. Epstein's work, which was based on what might be called an Epstein layer, was further developed in 1939 by K. Rawer with special reference to practical applications. At about the same time the present author studied the transmission-properties of the parabolic layer in the penetration-frequency region. The results were subsequently published.

In the present memoir the transmission-properties of the parabolic layer are studied throughout the long-, medium-, and short-wave regions. Suitable expansions of the wave-functions are developed for this purpose and it is also possible to investigate the accuracy of the phase-integral method originally developed by T. L. Eckersley.

The transmission of radio waves round the Earth surrounded by a concentric, parabolic layer is a problem of considerable interest in this connection. General formulas are obtained for the transmission of horizontally and vertically polarized waves. These formulas are applicable to any kind of layer provided its wave-functions and their circuit-relation have been found. The original series solution has been transformed into the physically simplest possible form. This makes it possible to split up the solution in subsidiary waves. This has already been done in the reflector free case by B. van der Pol and H. Bremmer in 1937. Following G. N. Watson the series solution is transformed into a contour-integral in the long-wave case. The residue series subsequently obtained is studied in detail and numerical examples are shown. For medium and short waves the subsidiary waves are transformed by the stationary-phase method to yield the amplitude and phase of the geometrical optical ray. The bridging between the long-wave and the medium-wave cases is also discussed.

It is also of considerable interest to study the attenuation-coefficient in long-wave transmission. In case of the horizontal polarization, for example, it is found that there normally is little difference between the inhomogeneous and homogeneous layers in the true long-wave case. Reasonable D-layer data yield attenuation-coefficients in good agreement with the empirical Austin ones. As an illustration of the actual nature of the propagation the magnitude of the ratio between the actual field and the so-called primary field has been plotted as a function of the sender-receiver distance in a typical long-wave case. This demonstrates the crude approximation of the Austin formula. A further study of the individual terms of the residue series then shows how radially standing waves are produced between reflector and ground as selected by the proper values or poles of the residue series. It is found that low-order waves are guided mainly by the reflecting shell contrary to the high-order waves where ground and reflector have a symmetrical attenuation-influence.

Finally the transmission-properties of the parabolic layer are studied from an ionospheric point of view. The influence of the electronic collisional frequency upon the transmission-coefficients and the so-called virtual height is discussed theoretically and numerically with special reference to practical conditions. Numerical results are shown for layers of variable thickness. In conclusion as a by-product the transmission properties of the extremely thin layer have been deduced with special reference to the discussion of the nature of the so-called abnormal E-reflections.

Author

C. COLERIDGE FARR, 1866-1943*

Dr. C. Coleridge Farr, F.R.S., for 30 years a member of the Canterbury Branch of the Royal Society of New Zealand, and an original Fellow of the Society, died on January 27, 1943.

Farr was born in Adelaide on May 22, 1866. His father, the Venerable Archdeacon Farr, LL.D. (Cantab.), was, at the time, headmaster of St. Peter's College, the leading Boys' College in Adelaide. After receiving his early education at his father's school, Dr. Farr proceeded to Adelaide University. It was his good fortune that Sir William Bragg was Professor of Mathematics and Physics. Farr remained a lifelong friend of Sir William and his family, and he was fond of recalling that he had often nursed on his knee Professor W. H. Bragg, at present the Cavendish Professor of Physics at Cambridge.

From Adelaide he proceeded to a course in Engineering at Sydney University. He was awarded the Angus Engineering Scholarship in 1889. This scholarship took him to University College, London, but a period of ill health in England compelled him to return to Sydney. He was a lecturer in mathematics and physics at Sydney University from 1891 to 1895, and a lecturer in electrical engineering at Adelaide in 1896.

In the same year Farr suggested to P. Barracchi, Government Astronomer for the colony of Victoria, that a magnetic survey in southern latitudes was urgently needed. An extensive survey of Great Britain by Professors Rucker and Thorpe had just been completed. Farr considered that a similar survey of New Zealand could be carried out. The project was taken up by the Kew Observatory, of which Dr. Charles Chree was the Superintendent, and also by the Royal Society. Instruments were lent by the Royal Society and the work was outlined in 1898. Observations were commenced in February, 1899, by Farr, assisted by W. T. Neill. The early observations were taken from Dunedin to Invercargill and Stewart Island. On the return to Dunedin, H. F. Skey took the place of Mr. Neill as assistant. The work of observation was extended over the whole of New Zealand, and covered a period of ten years. In 1904, when Farr was appointed a lecturer in physics and civil engineering at Canterbury College, Mr. Skey took charge. Assistant observers included Messrs. E. Kidson, Pemberton, Walsh, Cook, and Bogle.

The results obtained from these observations were later analyzed and discussed by Farr—the author of this article assisting in a minor way—and published by the Lands and Survey Department under the title of "A magnetic survey of the Dominion of New Zealand." From the observations mean values of the declination, horizontal force, dip, northerly, easterly, vertical, and total lines of force were calculated for every 10° of latitude. Maps were prepared showing these values, and also showing the magnitude and direction of the deviation of each local station from the calculated survey of the magnetic elements for New Zealand for the epoch June 30, 1903. Mr. Baird, at present in charge of the Observatory, is carrying out a resurvey of many of the stations established by Farr and Skey.

*Reprinted from Trans. and Proc. R. Soc. New Zealand, **73**, xlv-xlviii (1943).

From 1904 to 1910 Farr acted as lecturer in physics at Canterbury College, and when a chair in Physics was established in 1910 he was appointed professor. Under his direction the present Physical Laboratory at Canterbury College was built in 1916. After a long apprenticeship in anterooms and a tin shed it seemed palatial, but it is proving inadequate for modern requirements.

While at Sydney University, Farr published a paper in the *Proceedings of the Royal Society* entitled "Some expressions for the radial and axial components of magnetic force of a solenoid." During the time he was at the Magnetic Observatory he published two papers entitled "Some observations on the rate of dissipation of electric charges in open air" and "Interpretation of Milne seismograms," the former in the *Proceedings of the Royal Society* and the latter in the *Philosophical Magazine.*

The present Observatory in Christchurch was established by Farr under the New Zealand Government to carry on the work begun in the field. The scope of its operations has been extended from time to time. It constitutes an important link in the chain of world observatories, and through it, Christchurch in particular and New Zealand in general have figured prominently in assisting the scientific staffs of the various famous antarctic expeditions, setting out from here as their last important place of call. It has also proved a valuable training place for a number of men who later filled important posts in magnetic and meteorological work. Farr retained a strong interest in magnetic research throughout his life. After his retirement from the professorship of physics he undertook further investigations for Sir Douglas Mawson.

While acting as lecturer in physics, Farr, with the assistance of Professor Florence, measured the radioactive content of typical rocks collected from various parts of New Zealand and from the subantarctic islands. The radioactivity of the local artesian waters was also measured. Papers on this work were published in the *Philosophical Magazine* and the *Transactions of the New Zealand Institute.* Farr maintained that there was strong evidence that the trouble experienced in breeding trout fry in the waters, direct from the wells, in Christchurch was due to their radioactivity. As the waters were also deficient in oxygen, it was difficult to come to a definite conclusion. Aerating, which seemed to remove the trouble, at the same time reduced the deficiency of oxygen and caused the waters to lose their radioactivity. The high radioactive content of the local waters was definitely established.

An early association with Professor Threlfald, of Sydney University, interested Farr in the physical properties of liquid sulphur. Much time and effort was spent with the author of this article in carrying out investigations on this subject. Two papers, "The viscosity of liquid sulphur" and "Some physical properties of gas-freed sulphur," were published in the *Proceedings of the Royal Society.*

Meantime, considerable trouble had been experienced with the Lake Coleridge installation, due to the breaking down of insulators. Farr designed and had constructed a large steel container capable of holding a full-sized insulator and retaining a pressure of 1,000 pounds per square inch over a period of a month. Insulators were placed in this pot in colored water and subjected to this heavy pressure for a long period. Subsequent examination showed that the class of insulator breaking

down was porous. Papers entitled "Tests and investigations on high tension insulation" and "Porosity of porcelain, with special reference to high pressure insulators for electric transmission lines" were published in the *Journal of the American Institute of Electrical Engineers* and in the *New Zealand Journal of Science and Technology.* This work pointed the way to improved methods of manufacture, and was a guide to the Government in buying insulators from various firms.

With the assistance of N. M. Rogers, Farr carried through a laborious survey of the helium-content of New Zealand's natural gases. Samples were collected from all over New Zealand and analyzed in the laboratory. Farr, traveling on a motorcycle with side-chair, personally collected the samples from many parts of the North Island, and, needless to say, had many adventures in the process. This work and other researches that were being carried out in the laboratory would have been impossible but for a liquid-air plant which Farr installed in the workshop. Incidentally, the liquid air provided the material for many excellent lectures and demonstrations. The results of the helium survey were published in the *Journal of Science and Technology of New Zealand* in a paper entitled "Helium in New Zealand." It is interesting to note that the highest helium content came from Hanmer, but that nowhere was there sufficient to be of commercial interest.

In the latter part of his term as Professor of Physics, Farr was engaged with C. T. Banwell on an investigation on the possible effect of a transverse magnetic field on the velocity of light. Two papers on this work were published in the *Proceedings of the Royal Society*, one in 1932 and the second in 1940. Though the results of the experiments seemed to indicate that the field caused a slight increase in the velocity of light, the issue remained uncertain, and any increase was not greater than one part in one hundred million.

Farr retired from the Chair of Physics in 1936.

As a teacher, Farr was very popular with his students and his associates. His method of lecturing, often unconventional, and well interspersed with analogies and jokes, was stimulating and effective. His public addresses on the progress of his subject were notable. As a personal friend and keen admirer of Lord Rutherford, he gave Canterbury College students every opportunity to be acquainted with the progress in atomic physics as it unfolded through the years.

Farr was closely associated with the Canterbury Branch of the Royal Society from the time of his arrival in New Zealand. He was Secretary of the local Society in 1903, 1904, 1907, and 1912, and President in 1905 and 1919. He represented the Canterbury Branch on the Council of the Society for a long period of years, and was President of the New Zealand Society in 1929-30. He was Hector Medallist in 1922.

Farr was elected in 1928 a Fellow of the Royal Society of London, an honor coveted by all British scientists and conferred on very few. His pioneering work in connection with the magnetic survey and his extremely active interest in the cause of science in New Zealand made his claim to election a strong one.

Farr acted as New Zealand Secretary to the Australasian Association for the Advancement of Science for many years. He was prominently associated with various expeditions carried out by the local Society,

notably that to the subantarctic islands of New Zealand. He was a delegate to the Pan-Pacific Conference in Japan in 1926. He brought back from that Conference a keen sense of the danger to our civilization after observing the combination of the high efficiency and a low standard of living among the Japanese. He also brought back a fund of humorous stories and incidents.

It is worth recording that when he returned to do a little wartime teaching at his old school, after retiring from Canterbury College, he was immediately dubbed "Mr. Chips" by the boys.

Farr's influence in New Zealand has been an important one. But for his enthusiasm, the establishment of a magnetic observatory in this country might have been postponed for many years. His personal acquaintance with many prominent men in his own subject and other branches of science was a valuable help to those of his students who went abroad, and enabled him to stimulate an interest in research in this country. He always maintained that one of the chief functions of a university is the extension of knowledge, and in support of this he was fond of quoting the remark that students are a necessary excrescence on the university system.

Farr's health had, undoubtedly, caused him considerable anxiety over the latter years of his life, but though his health was failing, his end came somewhat suddenly and unexpectedly. He was spared what might have been many months of suffering.

He is survived by his wife and an only son, who holds a commission in the Royal Navy.

D. B. M(acleod)

REVIEWS AND ABSTRACTS

(See also pages 254 and 269)

OLOF E. H. RYDBECK: *A theoretical survey of the possibilities of determining the distribution of the free electrons in the upper atmosphere.* Göteborg, Chalmers Tekniska Högskolas Handlingar, No. 3, 74 pp. (1942).

The problem of determining the variation with height of the density of the free electrons of the upper ionosphere has attracted a great deal of interest during the past two years. The same is true of the problem of determining the variation of the electronic collisional frequency with height, a problem of a very similar nature. The present communication is a theoretical survey of the fundamentals which are of main interest in connection with these problems.

The measurement of the travel-times of electromagnetic wave-packets forms the basis of almost all ionospheric measurements. As an introduction, therefore, the propagation and dispersion of the wave-packet is treated by means of well-known optical methods. Several examples are shown of the actual dispersion of down-coming wave-trains. Under most conditions the dispersion is not serious and the determination of the time of travel is fairly accurate.

A closer approximation to the actual wave-solution than that afforded by the geometrical optics is studied by means of approximations of Brillouin, Wenzel, and Kramers. A practical example of standing waves between the ionosphere and ground is shown. As the difference between the classical phase and the B. W. K.-phase is independent of the wave-frequency, the time of travel becomes the same in both cases. When the time of travel is known as a function of the wave-frequency it is generally possible to determine the distribution of the free electrons over most of the lower part of the ionized layers. The various mathematical methods to be used for this purpose are studied fairly thoroughly. It is shown that quite accurate solutions can be obtained at places where the magnetic inclination is either great or small.

The next problem discussed is the calculation of the variation of the collisional frequency with height. It is interesting to find that it can be determined from sweep-frequency reflection-coefficient measurements, if the electron-density distribution is determined at the same time. So far the method has not been applied in practice. Even though the necessary measuring equipment is fairly complicated the prospects of getting valuable results are good.

A number of ionospheric records have been examined and the corresponding electron-density distribution studied. It is shown that it generally is parabolic over a quite wide density-range. Examples are shown where the parabolic representation is a very good approximation for practically the whole layer. The characteristic frequencies have been obtained for each distribution and it is shown that it generally is not a permissible approximation to use a fixed ratio of characteristic frequency to critical frequency in the routine scaling of ionospheric records. The total number of electrons has been integrated for several cases and it is shown that this number may decrease even though the maximum electron-density increases, as is often the case in the afternoon in the equatorial regions. This strongly supports the various hypotheses of the expansion of the upper atmosphere.

Finally the exact wave-functions for a parabolic layer are studied briefly. It is shown that the travel-time and the dispersion are finite at the critical frequency and the reflection-coefficient differs appreciably from the classical one only when the layer-thickness becomes less than about four wave-lengths.

AUTHOR

M. WALDMEIER: *Ionosphärische Bestimmung der UV-Intensitäten der Sonnenstrahlung im Bereich* 700-900 Å. Helv. Phys. Acta, **17**, No. 3, 168-180 (1944).

Es wird gezeigt, dass der Ausdruck $f^n{}_0/\cos\chi$ (f_0 = Grenzfrequenz der E-Schicht, χ = Zenitdistanz der Sonne) proportional ist der extraterrestrischen Intensität der die E-Ionisation erzeugenden Strahlung. Empirische Bestimmung des Exponenten ergab $n=3$ (im Gegensatz zu dem bisher angenommenen Wert $n=4$). Die berechneten Intensitäten zeigen einen jährlichen Gang mit gut definiertem Maximum im Dezember/Januar und einem flachen Minimum im Spätsommer, welcher auf den jahreszeitlichen Gang der Ionosphärentemperatur zurückgeführt wird. Die nach Elimination der

jährlichen Periode erhaltenen extraterrestrischen Intensitäten S_0 der E-Strahlung zeigen in den Monatsmitteln eine sehr enge Korrelation mit der durch die Fleckenrelativzahl R ausgedrückten Sonnenaktivität. Die Beziehung zwischen S_0 und R ist linear; zur Zeit des Sonnentätigkeitsmaximums ist S_0 rund doppelt so gross als zur Zeit des Minimums. Es wird gezeigt, dass die E-Strahlung, die wahrscheinlich in der Gegend von 700-900 Å liegt, in ihren statistischen Eigenschaften (Amplitude, Linearität, Korrelation) mit denjenigen der von Bartels aus den sonnentätigen erdmagnetischen Variation erschlossenen W-Strahlung übereinstimmt, woraus folgt, dass diese Variationen ausschliesslich aus die E-Ionisation, also ein Stromsystem in rund 110 km Höhe zurückzuführen sind.

AUTHOR

LETTERS TO EDITOR

(See also page 238)

GEOPHYSICAL WORK IN THE UNION OF SOVIET SOCIALIST REPUBLICS

For a better understanding of geophysical operations in the U. S. S. R. I should like to give some details concerning our work during the last few years.

The Institute of Terrestrial Magnetism was established in 1940. At first we had only two sections, namely, (1) a group for magnetic survey on land in Leningrad and (2) a magnetic observatory at Pavlovsk (Slutsk). A short time afterward, several new groups were organized as follows: for magnetic survey at sea; magnetic cartography; theoretical investigations; superintendence of magnetic observatories; and some others. The Slutsk Ionospheric Station and the Magnetic Observatory were incorporated into the Institute.

At that time the Institute concentrated its survey-activities chiefly in the western regions of the country. Some measures were undertaken to establish magnetic standards of the U. S. S. R. on the basis of the suitable instruments of the Institute and of the magnetic observatories. For comparing the instruments of the observatories two sets of *QHM* (after la Cour) were constructed. Various methods of temperature-compensation of magnetic instruments were examined. Attention was given to the problem of forecasting magnetic disturbances.

A new magnetic and earth-current observatory was in process of construction near Novgorod where recording of earth-currents was started not long before the war. The Yanov (Lvov) Magnetic Observatory was restored after its instruments had been damaged by the Germans in 1939. All this is, of course, only a short summary of the work carried out by us before the war.

In 1941-42 six magnetic observatories in Yanov, Stepanovka, Novgorod, Amvrossievka, Nizhnedevitsk, and Pavlovsk were temporarily occupied by the Germans. The personnel and equipment of these observatories were partly evacuated and partly captured by the enemy.

In the winter of 1941-42 the Institute worked in besieged Leningrad. In the early spring of 1942, it was moved from Leningrad to the magnetic observatory of Vyssokaya Dubrava, near Sverdlovsk. In 1942-43 there were completed two two-story buildings for office and living quarters and seven one-story buildings for the ionospheric station, field-intensity observations, a solar station, power-station, and other purposes.

In spite of wartime difficulties we had restored the work of the Institute in a new place and even somewhat extended it. Regular observations are organized and preparations made for carrying out spectroheliographic and cosmic-ray-intensity observations.

The direct-reading declinometer and the la Cour type of *BMZ* for field-measurements were constructed. The general magnetic survey and observations at the repeat-stations were continued. Some arduous magnetic expeditions were completed in the north of Siberia during the war.

Several expeditions were sent to study magnetic anomalies connected with useful mineral deposits. The work on magnetic cartography was greatly extended. Several papers on normal field, secular change, and magnetic storms were prepared and will soon be published in the *Transactions* of the Institute.

Magnetic and ionospheric services of the U. S. S. R. are now conducted by our Institute. We collect solar, magnetic, and ionospheric data and distribute them to the authorized agencies by wire and through ten-day reviews of cosmic data. The preparation of the magnetic data from the magnetic observatories for publication is kept current.

Such is our work during wartime. The Government has highly appreciated our work and decorated some members of our staff by orders and medals of the U. S. S. R.

The retreating German army of occupation burned and blew up all the buildings of our Institute in Pavlovsk, Novgorod, and Nizhnedevitsk; the only building which escaped complete destruction is the variation-house in Pavlovsk. The fate of the equipment, observational records of the Pavlovsk Observatory, and magnetograms of the stations of the Second International Polar Year which were captured by the enemy, is unknown. Several members of our staff died during the siege of Leningrad, among them Professors Weinberg and Trubyatchinsky.

Great and hard tasks lie before us; first of all the construction of the Institute at a new site near Moscow, and the reestablishment of the magnetic observatories destroyed by the Germans. Notwithstanding the large losses in the members of the staff, equipment, and facilities, we hope that we shall be able to create a powerful center of research for geomagnetism in our country.

N. Pushkov

Vyssokaya Dubrava, U.S.S.R., July 21, 1944

SOLAR AND MAGNETIC DATA, JULY TO SEPTEMBER, 1944, MOUNT WILSON OBSERVATORY

The magnetic storm of August 2 to 3 occurred during a quiescent period on the Sun. This storm began at 12^h GMT, August 2, and ended at 10^h, August 3, with a range in H of 185γ. On August 18, a magnetic disturbance occurred from 06^h to 13^h GMT (=GCT). The range in H was 75γ. No sunspots were observed from July 31 to August 4.

TABLE 1—*Solar and magnetic data*

Day	July 1944						August 1944						September 1944					
	K_2		H_α	H_α	No.	Mag'c	K_2		H_α	H_α	No.	Mag'c	K_2		H_α	H_α	No.	Mag'c
	Whole disk	Central zone	bright	dark	groups	char.	Whole disk	Central zone	bright	dark	groups	char.	Whole disk	Central zone	bright	dark	groups	char.
1	0	0	0	1	0	0	0	0	0	1	0	0	2	1	2	1	2	0
2	0	0	0	1	1	0	0	0	0	1	0	0.5	2	1	2	1	2	1
3	0	0	0	1	1	0	0	0	0	2	0	1.5	2	1	2	1	1	0.5
4	1	0	1	2	1	0	0	0	0	1	1	0	2	1	2	1	0	0
5	1	0	1	2	1	0	1	0	1	2	2	0	1	1	1	2	0	0
6	1	0	1	2	1	0	1	1	1	2	2	0	1	1	1	2	0	0.5
7	1	0	1	2	0	0.5	1	0	1	2	2	0	1	1	1	3	1	0
8	1	0	1	2	0	0	1	0	2	2	3	0	1	0	1	3	0	0
9	1	0	1	2	1	0.5	..	..	..	..	3	0	0	0	0	3	1	0
10	1	1	1	2	1	0	..	..	..	..	3	0.5	1	1	1	3	1	0
11	1	1	1	2	1	0	..	..	..	..	4	0.5	1	1	1	2	1	0
12	1	1	0	2	0	0	2	1	2	2	4	0	1	0	2	2	1	0.5
13	1	0	0	2	0	0	2	0	2	2	3	0	2	1	2	2	1	0
14	0	0	0	2	0	0	2	1	2	1	3	0	2	1	2	1	1	0
15	0	0	0	1	0	0.5	2	1	2	1	3	0	2	1	2	1	1[k]	0
16	0	0	0	2	0	0	2	1	2	1	2	0	1	1	1	1	1	0
17	0	0	0	2	0	0.5	2	1	2	1	3	0	1	0	1	1	1	0
18	0	0	0	2	1	0	2	2	2	1	3	0.5	1	0	1	1	1	0.5
19	0	0	0	1	1	0	1	1	2	1	3	0	1	0	1	1	2[b]	0
20	0	0	0	1	1	0.5	2	1	2	1	2	0	1	0	1	1	2	0.5
21	0	0	0	1	0	0.5	1	1	1	1	1	0	1	0	1	1	2	0.5
22	1	1	1	2	1	0.5	2	0	1	1	1	0	1	0	1	1	1	0
23	1	1	0	1	1	0	1	0	2	1	2	0	1	1	1	1	1	..
24	1	1	1	1	1	0	1	1	1	1	2	0.5	1	1	1	1	1	0.5
25	1	1	1	1	1	0	2	1	2	0	3	0	1	0	1	1	1	0.5
26	1	1	1	1	1	0	2	1	2	0	2	0	1	0	2	1	1	0.5
27	1	1	1	1	1	0	2	1	2	0	2	0	1	0	2	1	1	0.5
28	1	1	1	2	1	0	2	0	2	0	2	0.5	1	0	1	2	1	0
29	1	0	1	1	1	0	2	1	2	1	2	0	1	1	1	2	3[a]	0
30	1	0	1	1	1	0	2	0	2	1	2	0	..	..	1	2	1	0.5
31	1	0	1	1	0	0	2	0	2	1	1	0.5						
Mean	0.6	0.3	0.5	1.5	0.6	0.1	1.4	0.6	1.5	1.1	2.1	0.2	1.2	0.6	1.3	1.5	1.1	0.2

NOTE—For an explanation of these tables see this JOURNAL 35, 47-49 (1930).

The character-figures of solar phenomena are estimated from the spectroheliograms which are made with a 2-inch solar image, usually in the early morning. Solar flares are reported in these notes if observed at any time during the day.

[a, b]Formation of a new group which later developed to average size or larger; (*a*) less than 30° from the center of the disk, (*b*) more than 30° from the center of the disk.

[c, d]Solar flares: (*c*) less than 30° from the center of the disk, (*d*) more than 30° from the center of the disk.

[e, f, g, h, i, j, k, l] Passage of a large or active group across the central meridian within 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40° of the center of the disk, respectively.

CARNEGIE INSTITUTION OF WASHINGTON,

SETH B. NICHOLSON

PRINCIPAL MAGNETIC STORMS

Sitka Magnetic Observatory

July to September, 1944

(Latitude 57° 03′.0 N., longitude 135° 20′.1 or 9^h $01^m.3$ W. of Gr.)

August 2-3—Climaxing a three-month period of unusual calm a fairly severe storm began gradually about 21^h GMT, August 2, accelerated at 24^h, and diminished sharply in intensity after 11^h, August 3. A maximum positive departure from normal of 625 gammas occurred in horizontal intensity at 03^h 32^m and *K*-indices of 7 were recorded for the first three periods of August 3. Most of the action on *D* took the form of rather long-period oscillations.

August 18—A brief disturbance consisting principally of a single swing off and a more gradual recovery occurred between 08^h and 12^h GMT, August 18. Ranges: *D*, 33′; *H*, 442 gammas; *Z*, 430 gammas (relatively larger than usual).

Harold W. Pinckney, *Observer-in-Charge*

Cheltenham Magnetic Observatory

July to September, 1944

(Latitude 38° 44′.0 N., longitude 76° 50′.5 or 5^h $07^m.4$ W. of Gr.)

August 2-3—A rather severe storm began, after some hours of minor activity, at about 21^h GMT, August 2, and ended at about 12^h, August 3. Throughout the storm, the longer-period fluctuations predominated. The greatest activity occurred in declination, the total range of which was just over 1°. *K*-indices of 7 were recorded for the first two three-hour periods of August 3, and indices of 6 for the next two periods.

August 18—A bay beginning at 07^h 54^m GMT, August 18, resulted in a *K*-index of 6. All three elements were affected.

September 2—A minor disturbance began at about 00^h GMT, September 2, and lasted approximately twelve hours. Three successive *K*-indices of 5 were recorded.

September 21—A deep bay in declination beginning at 02^h 11^m GMT, September 21, gave a *K*-index of 6.

September 23-24—Two bays in declination accompanied by minor short-period activity beginning at 19^h GMT, September 23, and lasting about fifteen hours, resulted in *K*-indices of 5 for the first, third, and fourth three-hour periods of September 24.

September 30—A disturbance began at about 12^h GMT, September 30, and ended indefinitely about twelve hours later. There were two bays in horizontal intensity and a small one in declination, together with a moderate amount of short-period activity. Three successive *K*-indices of 5 were recorded.

John Hershberger, *Observer-in-Charge*

Tucson Magnetic Observatory

July to September, 1944

(*Latitude 32° 14′.8 N., longitude 110° 50′.1 or 7^h 23^m.3 W. of Gr.*)

August 2-3—A rather severe storm began about 12^h GMT, August 2. Between 12^h and 22^h the activity was rapid and of small amplitude. Following this period there were large variations in *D* and *H*, continuing until about 11^h, August 3, at which time the storm ended quite suddenly. Ranges: *D*, 22′; *H*, 183 gammas; *Z*, 51 gammas.

September 20-21—A moderate disturbance of only about twelve hours' duration began at about 21^h GMT, September 20. The outstanding features were two bays in *H*, the first beginning at about 21^h 25^m and the second at about 01^h, September 21. Ranges: *D*, 9′; *H*, 95 gammas.

September 23-25—A storm began about 17^h GMT, September 23. There was moderate activity in *D* and *H* for about seventeen hours, followed by minor variations until the end of the disturbance at about 06^h, September 25. A pronounced bay in the east declination occurred between 08^h and 10^h, September 24. Ranges: *D*, 11′; *H*, 96 gammas.

September 30-October 1—A moderate storm began about 13^h GMT, September 30. There was little activity except for three prominent bays in *H*, beginning at 14^h, 18^h, and 22^h. Small variations continued until about the end of October 1. Range in *H*, 90 gammas.

J. H. Nelson, *Observer-in-Charge*

Watheroo Magnetic Observatory

July to September, 1944

(*Longitude 30° 19′.1 S., longitude 115° 52′.6 or 7^h 43^m.5 E. of Gr.*)

September 30—Between 13^h and 16^h GMT, September 30, there was a large bay and peak shown in all three elements. The first feature was most clearly shown in the *H*-trace and *H* reached its minimum value at 14^h 47^m. Thereafter *H* quickly increased until it reached its maximum value at 15^h 05^m. A corresponding bay in the *Z*-trace culminated at the same time, while the westerly declination reached a minimum value at 15^h 04^m. Ranges: *D*, 11′.2; *H*, 77 gammas; *Z*, 88 gammas.

W. C. Parkinson, *Observer-in-Charge*

NOTES

(See aslo page 265)

38. *Rectangular magnet wire*—The following note is extracted from the *Review of Scientific Instruments* [**15**, p. 212 (1944)].

Formex (registered at U. S. Patent Office) ribbon-rectangular magnet-wire available in shapes as thin as 0.004 inch has been announced by the General Electric Company. It is one-fourth the size heretofore considered the low limit for thickness of this wire. Smooth, strong, flexible, and able to withstand high-speed winding without damage to insulation, it offers many possibilities of application to producers of electric components. In coil-winding, varnish-treatment, assembly, and actual operation, this new, ribbon-rectangular magnet-wire, like Formex in all other shapes, presents many advantages. Its final dielectric strength, judged by its reaction to abrasion and winding, and its resistance to heat-shock and solvents, are greater than that of other enameled wire. Moreover, tests to determine heat-aging, flexibility, and thermoplastic flow have proven its superiority over conventional enameled wire.

Because of its thinness, Formex ribbon-rectangular wire can be applied where round wire previously had to be used. In addition, it will substantially increase the winding-space factor and may be used in place of larger-size, rectangular magnet-wire to increase magnetic effect or reduce coil-size. (General Electric Company, Schenectady, New York.)

39. *Cosmic-ray expedition*—A group of scientists from the Lebedev Institute of Physics of the U. S. S. R. Academy of Sciences has left for the Pamir Mountains to study cosmic rays at high altitudes. The Expedition, under the direction of Professor D. V. Smobeltsyn, will continue studies that have been carried on for several years at the Atomic Nucleus Laboratory on Mount Elbrus, the highest mountain in the Caucasus. The Pamir Mountains are located in southern Russia, where they reach into both Afghanistan and India. The main objective of the Expedition is to study the composition of cosmic radiations at high altitudes and determine the rôle played by heavy particles and secondary mesons first discovered in cosmic radiations in 1937. In conducting its studies, the Expedition will make use of a perfected proportional telescope and improved methods which the Atomic Nucleus Laboratory has developed. [From Science, **100**, p. 10 (1944).]

40. *Solar work at Royal Observatory, 1943-1944*—The following is extracted from the annual report on the Royal Observatory, Greenwich, in *Nature* [**154**, p. 307 (1944)].

The solar work calls for little comment. Sunspot-frequency has slowly fallen, no spots being recorded at all during February, and only one very small spot during April. The epoch of minimum activity has apparently been reached, and the first high-latitude spots of the new cycle appeared in May, 1943. Geomagnetic activity was considerable, however—one great storm and 20 smaller ones occurred, some of these latter falling in a 27-day cycle characteristic of storms at solar minimum.

It is surprising that one of the five short-wave radio fade-outs, which occurred during the year, did so when no spot was visible on the disk. Fade-outs of this type have hitherto been attributed to solar flares (chromospheric eruptions), which are associated almost exclusively with sunspots. It will be interesting if positive spectroscopic evidence can be obtained that this is an instance of a flare occurring unassociated with a spot.

41. *Magnetic disturbance and aurora, July 18, 1944*—The following notes are extracted from U. S. Hydrographic Bulletins of August 5 and 12, 1944.

An observer reports experiencing a disturbance of the ship's magnetic compasses as follows:

"(1) On July 18, 1944, at $08^h\ 45^m$ this ship was at latitude 18° 40′ north, longitude 124° 30′ west, steaming on course 282° true at 11.5 knots. For a period of one hour the magnetic compasses exhibited an unusual behavior. (2) Variation for this area is 12° east. Deviation of both standard and steering compasses was 2° west. During the time there were no unusual conditions aboard ship which would affect the magnetic compasses. (3) Following is a report of the behavior of both standard and steering compasses during time-intervals indicated of changes in ship's magnetic heading: $08^h\ 45^m$–$08^h\ 50^m$, 272° to 300°; $08^h\ 50^m$–$09^h\ 10^m$, 300° to 272°; $09^h\ 10^m$–$09^h\ 20^m$, 272° to 262°; $09^h\ 29^m$–$09^h\ 45^m$, 262° to 272°."

An observer reports that at $06^h\ 35^m$ GMT, on July 17, 1944, in latitude 48° 24′ north, longitude 125° 10′ west, a display of the aurora borealis in the form of white oscillating shafts rising to a height of 10°, between the bearings 000° and 045°, was observed. The light remained visible until $07^h\ 30^m$ GMT, same date. Sky, clear; visibility, excellent; wind, 270°; force, one knot; barometer, 30.28 inches; temperature of air, 60° F, of water at injection, 50° F.; course, 267°.

42. *Personalia*—Dr. *James B. Macelwane*, S. J., advises us that the Department of Geophysics, the Department of Geology, and the Central Station of the Jesuit Seismological Association have moved to new quarters in the Institute of Geophysical Technology at 3621 Olive Street, Saint Louis 8, Missouri. He requests that all mail be sent to that address.

We regret to record the death of Sir *Henry George Lyons*, F.R.S., meteorologist and geographer, on August 11, 1944, at the age of eighty years. For a number of years Sir Henry was the General Secretary of the International Council of Scientific Unions.

We are advised that Dr. *A. Ogg*, Director of the Magnetic Observatory, Hermanus, Cape Province, South Africa, will retire in March, 1945, at the age of 75 years.

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